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# *Nursery Performance of Full and Half-sib Progenies and Juvenile Screening for Selection in Rubber* (Hevea brasiliensis *Muell. Arg.*) *Breeding*

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*In order to report growth and yield performance of progenies of 2002-hand pollination programme and to discuss the observations* vis-à-vis *juvenile screening in* Hevea *breeding, test tapping at three years was carried out. Latex volume, instead of dry rubber, was collected as yield from each tapping. Dry rubber content (DRC) of top selections was determined for calculation of rubber yield. Distribution of seedlings in different girth, yield and DRC classes were studied. Mean range in latex yield noted in the full-sib progenies of Wickham × Wild accessions was 0.1 to 4.5 mL $t^{-1}$ $t^{-1}$ (mL per tree per tapping) while in Wickham × Wickham progenies it was 0.1 to 19.6 mL $t^{-1}$ $t^{-1}$. In the clonal half-sibs (HS), mean yield was low in HS progenies of RRII 105 and PB 330 while in RRII 414 and RRII 429 it was higher. Maximum latex yield noted from a tapping was 33.0 mL $t^{-1}$ $t^{-1}$. Dry rubber yield in the top 20% selections showed a range of 0.7 to 4.1 g $t^{-1}$ $t^{-1}$ (grams per tree per tapping). Mean yield from 10 tappings ranged from 7 to 41 g $t^{-1}$ $10t^{-1}$ (grams per tree per 10 tappings). DRC among the top 20% selections varied from 14.3% to 38%. In the low girth class only one was included in the top 20% of selections. Moderate and average girth classes each contributed 41 and 38 seedlings that included most of the top 20% of selections. It was concluded that test-tapping at age three, rather than at two, was more useful. Measurement of yield in terms of latex volume as opposed to that of dry rubber yield, can result in more accurate yield recording. Latex can be used for determining rubber content and biochemical and physiological determinants of yield that can further boost the probability of potential selections. For maximum genetic gain in juvenile selection, seedlings of moderate to high girth class and average yield seemed more promising.*

**Keywords:** test-tapping; seedling performance; nursery screening; juvenile selection

Like in other tree crops, in *Hevea* also, breeding, evaluation and release of clones is long, laborious and time consuming[1–3]. In its breeding, each cycle of hand pollination programme produces few hundred to several thousand new genotypes. Nursery evaluation of these is the first major step in selection of potential individuals that are carried forward for further evaluation. Method of evaluation currently practised in the nurseries for selection is test-tapping of seedlings at two to two and a half years of age[3–7]. As the yield obtainable

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from two-year-old seedlings in each tapping is very small, yield of a fixed number of tappings is allowed to accumulate in the collection cups after which the collection is coagulated, dried and weighed to know the yield of seedlings. In India, seedlings are tapped mostly on 1/2S d/2 6d/7 system of tapping[8–10] with yield recordings from 10 tappings, while in Malaysia 1/2S d/3 6d/7 is the standard system adopted with yield data collected in cycles of 10 tappings for three times (three months) and presented as mean of 3 values each of 10 tappings[4–7]. This method of yield recording has the disadvantage of not providing the information on the progress in yield over different tappings and the data of individual seedlings cannot be subjected to statistical treatment to extract simple statistical measures like standard deviation and coefficient of variation. In addition, accuracy of yield data suffers because of external contamination as the latex collection cups are left in the field till the completion of fixed number of tappings. The disadvantages associated with the collection of dry rubber yield data after a fixed number of tappings can be overcome if yield from each tapping is collected. It is extremely difficult to obtain dry rubber yield data from each tapping as the yield is utterly low. This problem can be addressed if latex volume can be measured directly. So far no attempt has been made to collect latex volume as yield and determine rubber content in latex of tapped seedlings from nursery experiments.

The available information on the results from nursery evaluations of seedlings following hand pollination programmes is very meagre and is restricted to studies on progeny evaluation for estimating quantitative genetic parameters[4,5,7,11,12]. These trials are conducted in statistically laid out experimental designs. In hand pollination programmes, as the sizes of progenies obtainable is extremely variable, statistically laid out evaluations are not feasible. Therefore, simple nursery evaluations are conducted and the results are not normally published. This has created a lacuna in information on bench mark levels in girth for initial culling and in yield for subsequent selection of potential individuals. The objectives of this paper are to report growth and yield performance of full and half-sib seedlings and to discuss the observations *vis-à-vis* juvenile screening in *Hevea* breeding.

## MATERIALS AND METHODS

### Plant Material and Seedling Nursery

Plant materials utilised in this study were the seedlings of hand pollination programme implemented during 2002 and established in a nursery at the Rubber Research Institute of India at Kottayam (9º 32' N, 76º 36' E, altitude 73 m asl), Kerala, South India. Crosses were made between Wickham clones and wild accessions (WA crosses) and among Wickham clones (WW crosses). Open pollinated (half-sib) seeds of Wickham clones that were used as female parents were also obtained. Details of Wickham clones and wild accessions involved can be found elsewhere[13]. A total of 1008 seedlings were established in the nursery out of which 76 seedlings were hybrids of WA crosses, 251 were hybrids of WW crosses and 681 were half-sibs of four Wickham clones that were used as female parents. Nursery of the seedlings was established during August/September 2002 following a spacing of 60 cm × 60 cm. In the first year of planting, during November 2002 to March 2003, the seedlings were maintained under irrigation twice a week to prevent casualties due to moisture and heat stress.

### Girth Data

Girth of the seedlings was collected from a height of 30 cm from the ground. The data were collected in November 2004 and 2005.



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All the seedlings were numbered and the girth measurements were made in the same position marked with paint (renewed every year) and the girth was always measured exactly along the paint mark using a non-stretching tailor tape calibrated in millimetres and the values were recorded to the nearest 0.1 cm.

**Selection of Seedlings and Test-Tapping**

Test-tapping was carried out on three-years-old seedlings at a height of 30 cm from the ground. Only the seedlings with a girth of 10 cm and above at a height of 30 cm from the ground were selected for test tapping. This cut-off girth was chosen because seedlings less than 10 cm girth appeared weaklings compared to vigorous ones and from the previous experience it was observed that it was very difficult to tap the lean seedlings and very rarely high yielding selections were spotted from such saplings.

**Yield Data**

In this study latex volume was collected as yield instead of dry rubber[14]. Graduated microcentrifuge/centrifuge tubes were used for latex yield. As the tapping progressed higher yielding seedlings were fixed with higher capacity tubes depending on the previous yield. After a few tappings, the seedlings that were giving noticeably high yield were tapped first on each tapping day. Tapping system followed was 1/2S d/2 6d/7. On completion of 22 tappings, all the seedlings that were giving a latex yield of less than 1.0 mL per tapping were excluded from further tapping as they were not likely to increase their yield any more. Unit of yield for the latex volume was mL $t^{-1}$ $t^{-1}$ (mL per tree per tapping) and that of rubber yield was g $t^{-1}$ $t^{-1}$ (grams per tree per tapping) and g $t^{-1}$ $10t^{-1}$ (grams per tree per 10 tappings).

**Data on Dry Rubber Content**

Dry rubber content (DRC) of latex was determined only for high yielding selections. Top performers were identified based on latex yield on completion of 22 tappings. Selections were restricted to 20% as recommended by Simmonds[3] (1989). DRC was estimated by gravimetric method using 5.5 mm diameter Petri plates. Two to three mL of latex (and in some cases the available yield) was taken in cleaned, dried and pre-weighed Petri plates and weighed again to get the weight of latex. The Petri plates with latex samples were dried overnight at 60ºC in an oven to obtain the total solid content (TSC) in known weight of latex which was then converted to percentage value. TSC was taken as DRC as there is negligible difference between them. Five determinations were done for each selection and the mean was taken as typical DRC for the selection.

**Anatomical Attributes**

Data on bark thickness and number of latex vessel rows were collected from all the seedlings that were tapped. One square cm sample of bark piece was chiselled out from each seedling using a bark sampler at a height of 30 cm from the ground and fixed in formalin-acetic acid-alcohol fixative[15]. Radial longitudinal sections were cut on a sliding microtome, stained in Oil Red O and the data were collected from the sections using Projectina microscope. Three observations were recorded and the mean was obtained to represent the measurements for each seedling.

**Weather Data and Statistical Analysis**

Data on rainfall for the study period and for three months prior to tapping were collected from the observatory maintained in the station. Wherever necessary, data were subjected

to simple statistical analysis and statistical parameters like frequencies under different classes and categories, standard deviation and coefficient of variation were calculated. Correlations of latex volume and dry rubber yield with girth, bark thickness, number of latex vessel rows and dry rubber content were worked out.

## RESULTS AND DISCUSSION

Weather conditions were mostly dry for about 60 days prior to start of tapping (*Figure 1*). This situation prevailed for another 18 days after which it was raining intermittently due to premonsoon thunderstorm activity that is typical of the location. Test-tapping was started on 14th February 2006 and stopped on 16th May 2006 after completing 35 tappings. Towards the latter half of tapping activity test-tapping was disrupted on many days mainly due to interference from rain.

Growth performance of all the survived seedlings (*Table 1*) indicated higher mean girth (14.7 cm) for the progenies of RRII 429 × MT 1021 with a range of 10.8 cm and 20.3 cm among the WA seedlings. In the WW progenies, seedlings of RRII 414 × PB 330 recorded higher mean girth (14.7 cm) with a range of 7.1 to 24.3 cm closely followed by reciprocal progenies of the same cross with a mean of 13.6 cm and a range of 3.8 to 34.2 cm. In the half-sib category, progenies of all the parents were comparable. Overall variability in girth across all seedlings was about 43.7%. Variability in girth of seedlings steadily increased from age 1 to age 3 (data not given).

Mean latex yield noted in the WA progenies was 0.7 mL $t^{-1}$ $t^{-1}$ with a range of 0.1 mL $t^{-1}$ $t^{-1}$ to 4.5 mL $t^{-1}$ $t^{-1}$ (*Table 2*). The maximum yielding (4.5 mL $t^{-1}$ $t^{-1}$) seedling in the WA category was a progeny of RRII 414 × MT 2226. Latex yield in WW progenies ranged from 0.1 to 19.6 mL $t^{-1}$ $t^{-1}$ with a mean of 1.9 mL $t^{-1}$ $t^{-1}$. Maximum yielding (19.6 mL $t^{-1}$ $t^{-1}$) seedling in this category was a progeny of PB 330 × RRII 414. In the clonal half-sibs, mean yield was low in RRII 105 and PB 330 seedlings while in RRII 414 and RRII 429 it was higher. Similarly mean maximum yield noted for RRII 414 and RRII 429 half-sibs were comparatively higher than the other two clones. In high yielding seedlings, maximum latex yield noted from a tapping was 33.0 mL $t^{-1}$ $t^{-1}$. Yield variability, in general was very high in all the categories. The performance of progenies for dry rubber yield and rubber content in the top 20 percent selections and their distribution among different seedling sources (*Table 3*) showed an overall yield range of 0.6 to 4.1 g $t^{-1}$ $t^{-1}$. The mean yield from 10 tappings ranged from 10 to 15 g $t^{-1}$ $t^{-1}$. Dry rubber content among the top 20% selections varied from 14.3% to 38%. The lowest DRC (14.3%) was recorded from seedlings of cross PB 330 × RRII 414 and the highest (38.0%) in the HS seedlings of RRII 414. Out of a total of 443 test-tapped seedlings, two (0.5%) were selected from WA group, 37 (8.4%) from WW group and 51 (11.5%) from the HS group.

Among the test-tapped seedlings, 52.6% (233 seedlings) belonged to low girth (< 15 cm) class group, 34.3% (152 seedlings) to moderate girth (15-20 cm) class, 10.6% (47 seedlings) to average girth (20-25 cm), 2.3% (10 seedlings) to high girth (25-30 cm) and 0.2% (one seedling) to very high girth class (*Table 4*). From the low girth class only one got included in the top 20% of selections. Moderate and average girth classes each contributed 41 (9.1%) and 38 (8.4%) seedlings that included most of the top 20% of selections. Nine seedlings were selected from high girth class and one from very high girth class. In terms of yield, only one seedling that was selected was a low yielder. In the moderate girth class, 59% were low yielders, 39% were

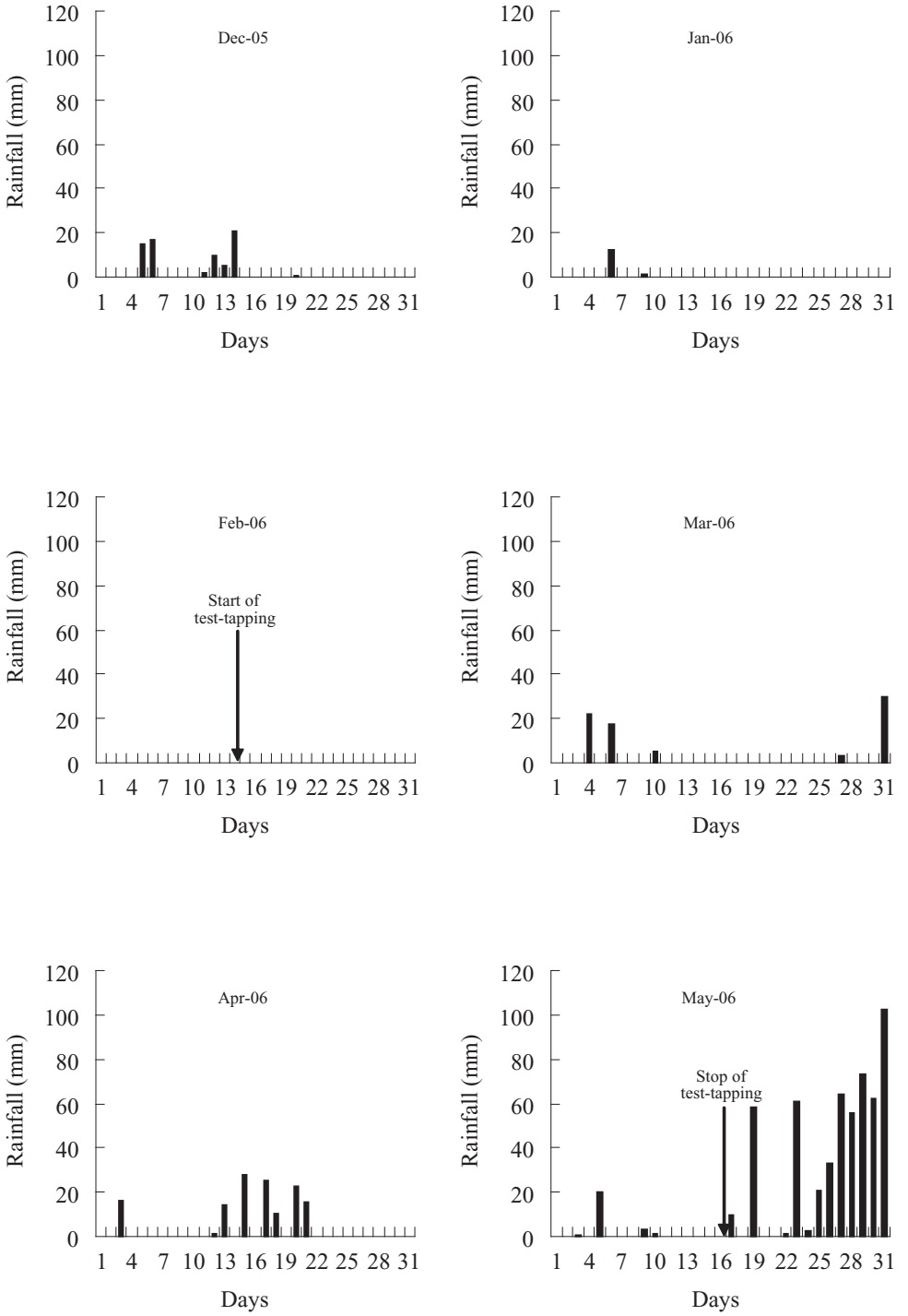


*Figure 1. Rainfall pattern in the period prior to and during test-tapping.*

TABLE 1. GROWTH PERFORMANCE OF FULL-SIB AND HALF-SIB PROGENIES IN NURSERY AT AGE 3

| Type of Seedling | Girth (cm), November 2005 | | | | | |
|---|---|---|---|---|---|---|
| | No of seedlings | Mean | Min | Max | SD (±) | CV (%) |
| WA progenies | | | | | | |
| RRII 105 × AC 2004 | 2 | 8.9 | 8.7 | 9.1 | 0.3 | 3.2 |
| RRII 105 × AC 2584 | 2 | 10.1 | 7.9 | 12.2 | 3.0 | 30.3 |
| RRII 105 × RO 1739 | 2 | 7.7 | 6.0 | 9.4 | 2.4 | 31.2 |
| RRII 105 × MT 1057 | 4 | 12.4 | 7.2 | 19.8 | 6.0 | 48.5 |
| RRII 414 × AC 2004 | 2 | 10.6 | 5.3 | 15.9 | 7.5 | 70.7 |
| RRII 414 × MT 2226 | 28 | 13.4 | 4.9 | 25.1 | 5.3 | 39.4 |
| RRII 429 × RO 1739 | 2 | 12.2 | 10.6 | 13.6 | 2.3 | 18.5 |
| RRII 429 × MT 1021 | 3 | 14.7 | 10.8 | 20.3 | 5.0 | 33.6 |
| RRII 429 × MT 2226 | 19 | 9.7 | 5.3 | 15.2 | 2.7 | 27.5 |
| Pooled | 64 | 11.7 | 4.9 | 25.1 | 4.6 | 39.4 |
| WW progenies | | | | | | |
| RRII 105 × PB 330 | 8 | 9.8 | 5.6 | 14.0 | 3.2 | 32.5 |
| RRII 105 × IRCA 130 | 2 | 7.5 | 6.1 | 8.9 | 2.0 | 26.4 |
| RRII 414 × PB 330 | 16 | 14.7 | 7.1 | 24.3 | 5.7 | 39.1 |
| RRII 414 × RRIM 600 | 2 | 7.5 | 5.8 | 9.1 | 2.3 | 31.3 |
| RRII 429 × PB 330 | 6 | 12.1 | 5.5 | 17.0 | 4.5 | 37.0 |
| PB 330 × RRII 414 | 102 | 13.6 | 3.8 | 34.2 | 6.4 | 47.2 |
| PB 330 × RRII 429 | 74 | 12.8 | 4.5 | 21.5 | 4.4 | 34.6 |
| Pooled | 210 | 13.1 | 3.8 | 34.2 | 5.6 | 42.8 |
| Clonal half-sibs | | | | | | |
| RRII 105 × ? | 158 | 11.0 | 3.4 | 28.3 | 4.9 | 44.8 |
| RRII 414 × ? | 107 | 12.1 | 4.1 | 23.4 | 4.9 | 40.7 |
| RRII 429 × ? | 88 | 11.9 | 3.3 | 26.0 | 5.2 | 43.5 |
| PB 330 × ? | 122 | 11.4 | 3.6 | 26.0 | 5.2 | 45.8 |
| Pooled | 475 | 11.6 | 3.3 | 28.3 | 5.1 | 43.8 |
| All pooled | 749 | 11.9 | 3.3 | 34.2 | 5.2 | 43.7 |

SD = Standard deviation, CV = Coefficient of variation

average yielders and 2% were high yielders while in the average girth class, 42% were low yielders, 55% were average yielders and 3% were high yielders. From the high girth class, most of the selections belonged to the average and high yield group. The selection from the very high girth class turned out to be high yielders.

About 10% of selections (nine seedlings) were having an unacceptable percentage of rubber content, while 17.8% (16 seedlings) had acceptable DRC (*Table 5*). About 27% came under good DRC and 45.6% had excellent DRC. Out of the nine seedlings of unacceptable DRC class, low and average yielders were in equal proportions at 44.4% (four seedlings each with one seedling under the high yielding category. From the acceptable DRC category, five seedlings were of high yielding type with nine and two seedlings respectively under average and low yield category. No

TABLE 2. YIELD PERFORMANCE OF PROGENIES IN NURSERY AT AGE 3 (BASED ON 22 TAPPINGS)

| Type of Seedling | No of seedlings | Selected for tapping | | Latex volume yield (mL $t^{-1}$ $t^{-1}$)* | | | | |
|---|---|---|---|---|---|---|---|---|
| | | No. | % | Mean | Min | Max | SD (±) | CV (%) |
| WA progenies | | | | | | | | |
| RRII 105 × AC 2004 | 2 | – | 0 | – | – | – | – | – |
| RRII 105 × AC 2584 | 2 | 1 | 50 | 0.4 | 0.4 | 0.4 | – | – |
| RRII 105 × RO 1739 | 2 | – | 0 | – | – | – | – | – |
| RRII 105 × MT 1057 | 4 | 2 | 50 | 0.6 | 0.5 | 0.6 | 0.08 | 14.7 |
| RRII 414 × AC 2004 | 2 | 1 | 50 | 0.4 | 0.4 | 0.4 | – | – |
| RRII 414 × MT 2226 | 28 | 20 | 71 | 0.9 | 0.1 | 4.5 | 1.08 | 120.5 |
| RRII 429 × RO 1739 | 2 | 2 | 100 | 1.2 | 1.1 | 1.2 | 0.08 | 6.8 |
| RRII 429 × MT 1021 | 3 | 3 | 100 | 0.7 | 0.3 | 1.4 | 0.56 | 76.7 |
| RRII 429 × MT 2226 | 19 | 8 | 42 | 0.3 | 0.1 | 0.5 | 0.14 | 45.1 |
| Pooled | 64 | 37 | 58 | 0.7 | 0.1 | 4.5 | 0.9 | 116.1 |
| WW progenies | | | | | | | | |
| RRII 105 × PB 330 | 8 | 4 | 50 | 0.6 | 0.4 | 1.0 | 0.27 | 45.5 |
| RRII 105 × IRCA 130 | 2 | – | 0 | – | – | – | – | – |
| RRII 414 × PB 330 | 16 | 11 | 69 | 2.0 | 0.5 | 6.7 | 1.99 | 98.9 |
| RRII 414 × RRIM 600 | 2 | – | 0 | – | – | – | – | – |
| RRII 429 × PB 330 | 6 | 4 | 67 | 2.2 | 0.2 | 4.8 | 2.31 | 104.9 |
| PB 330 × RRII 414 | 102 | 72 | 71 | 2.5 | 0.1 | 19.6 | 3.76 | 148.7 |
| PB 330 × RRII 429 | 74 | 55 | 74 | 1.0 | 0.2 | 5.2 | 1.04 | 108.5 |
| Pooled | 210 | 146 | 70 | 1.9 | 0.1 | 19.6 | 2.9 | 152.4 |
| Clonal half-sibs | | | | | | | | |
| RRII 105 × ? | 158 | 79 | 50 | 1.0 | 0.1 | 6.5 | 1.17 | 112.5 |
| RRII 414 × ? | 107 | 64 | 60 | 1.5 | 0.1 | 8.3 | 1.67 | 109.5 |
| RRII 429 × ? | 88 | 50 | 57 | 1.3 | 0.2 | 8.1 | 1.31 | 98.5 |
| PB 330 × ? | 122 | 67 | 55 | 1.1 | 0.1 | 6.0 | 1.17 | 105.5 |
| Pooled | 475 | 260 | 55 | 1.4 | 0.1 | 11.4 | 1.6 | 112.3 |
| All pooled | 749 | 443 | 59 | 1.5 | 0.1 | 19.6 | 2.09 | 138.2 |

*mL per tree per tap

seedling under high yielding category was noticed in the good and excellent DRC class. Percentage of low yielding selections was higher under excellent DRC category while the same was true for the average yield class seedlings under acceptable and good DRC classes. Classification of seedling selections under different yield variability indicated low variability in low yielding and high variability in high yielding seedlings. Percentage of low yielders was low in WW progenies and high in HS progenies while percentage of average and high yielders were high in WW progenies and low in HS progenies (*Table 6*). High yielding selections in WW progenies was twice as that of HS progenies.

Bark thickness of the seedlings that were tapped varied from 1.2 to 4.3 mm in the WA progenies while in the WW progenies it ranged

TABLE 3. PERFORMANCE OF PROGENIES FOR DRY RUBBER YIELD IN THE TOP 20 PERCENT SELECTIONS AND THEIR DISTRIBUTION AMONG DIFFERENT SEEDLING SOURCES

| Type of Seedling | Total tapped | No. of selections | % of total tapped | Rubber yield g $t^{-1}$ $t^{-1}$ Mean | Range | g $t^{-1}$ $10t^{-1}$* | DRC (%) Mean | Range |
|---|---|---|---|---|---|---|---|---|
| WA progenies | | | | | | | | |
| RRII 105 × AC 2004 | – | – | 0 | – | – | – | – | – |
| RRII 105 × AC 2584 | 1 | – | 0 | – | – | – | – | – |
| RRII 105 × RO 1739 | – | – | 0 | – | – | – | – | – |
| RRII 105 × MT 1057 | 2 | – | 0 | – | – | – | – | – |
| RRII 414 × AC 2004 | 1 | – | 0 | – | – | – | – | – |
| RRII 414 × MT 2226 | 20 | 2 | 0.5 | 1.0 | 0.9-1.2 | 10.0 | 28.9 | 26.0-31.8 |
| RRII 429 × RO 1739 | 2 | – | – | – | – | – | – | – |
| RRII 429 × MT 1021 | 3 | – | – | – | – | – | – | – |
| RRII 429 × MT 2226 | 8 | – | – | – | – | – | – | – |
| Pooled | 37 | 2 | 0.5 | – | – | – | – | – |
| WW progenies | | | | | | | | |
| RRII 105 × PB 330 | 4 | – | – | – | – | – | – | – |
| RRII 105 × IRCA 130 | – | – | – | – | – | – | – | – |
| RRII 414 × PB 330 | 11 | 5 | 1.1 | 1.1 | 0.7-1.5 | 11.0 | 29.2 | 20.3-36.5 |
| RRII 414 × RRIM 600 | – | – | – | – | – | – | – | – |
| RRII 429 × PB 330 | 4 | 2 | 0.5 | 1.2 | 0.9-1.6 | 12.0 | 30.5 | 26.2-34.8 |
| PB 330 × RRII 414 | 72 | 22 | 5.0 | 1.5 | 0.7-4.1 | 15.0 | 26.6 | 14.3-37.3 |
| PB 330 × RRII 429 | 55 | 8 | 1.8 | 1.0 | 0.6-1.4 | 10.0 | 29.4 | 19.8-34.7 |
| Pooled | 146 | 37 | 8.4 | – | – | – | | |
| Clonal half-sibs | | | | | | | | |
| RRII 105 × ? | 79 | 9 | 2.0 | 1.1 | 0.6-1.5 | 11.0 | 29.3 | 21.8-35.8 |
| RRII 414 × ? | 64 | 17 | 3.8 | 1.0 | 0.6-2.1 | 10.2 | 26.5 | 16.6-38.0 |
| RRII 429 × ? | 50 | 11 | 2.5 | 1.1 | 0.8-2.3 | 11.0 | 30.2 | 20.0-35.6 |
| PB 330 × ? | 67 | 14 | 3.2 | 1.0 | 0.6-1.6 | 10.0 | 28.8 | 21.6-34.6 |
| Pooled | 260 | 51 | 11.5 | – | – | – | – | – |
| All pooled | 443 | 90 | 20.3 | – | – | – | – | – |

*Range for this unit is the range given under g $t^{-1}$ $t^{-1}$ multiplied by 10

from 1.1 to 5.5 mm (*Table 7*). HS progenies recorded a range of 1.0 to 4.5mm. Latex vessel rows ranged from 1 to 8 with a mean of about 4 among the progenies of different seedling sources. Correlations between yield and girth and yield and bark thickness were moderate to good, but the correlations between yield and latex vessel rows were weak (*Table 8*). In general, magnitude of the correlations observed for dry rubber yield was higher compared to latex yield. Correlation obtained for DRC with latex yield was of higher magnitude compared to the one obtained with rubber yield.

Girth, yield, rubber content and the anatomical characteristics in the top 5% selections indicated that the majority of high yielding seedlings were of high girth (*Table 9*). Mean maximum latex yield observed

TABLE 4. DISTRIBUTION OF LOW, AVERAGE AND HIGH YIELD SELECTIONS UNDER DIFFERENT GIRTH CLASSES

| Girth class (cm) | Quality | No. tapped | Percent of total | Inclusions in the top 20% selections | | Yield Class: Low (<1g $t^{-1}$ $t^{-1}$) | | | Yield Class: Average (>1 & <2 g $t^{-1}$ $t^{-1}$) | | | Yield Class: High (> 2 g $t^{-1}$ $t^{-1}$) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | | No. | % of total tapped | No. | % of girth class | % of total tapped | No. | % of girth class | % of total tapped | No. | % of girth class | % of total tapped |
| < 15 | Low | 233 | 52.6 | 1 | 0.2 | 1 | 100 | 0.2 | 0 | 0 | 0.0 | 0 | 0 | 0.0 |
| 15-20 | Moderate | 152 | 34.3 | 41 | 9.1 | 24 | 59 | 5.4 | 16 | 39 | 3.6 | 1 | 2 | 0.2 |
| 20-25 | Average | 47 | 10.6 | 39 | 8.4 | 16 | 42 | 3.6 | 21 | 55 | 4.7 | 1 | 3 | 0.2 |
| 25-30 | High | 10 | 2.3 | 9 | 2.0 | 2 | 22 | 0.5 | 4 | 44 | 0.9 | 3 | 33 | 0.7 |
| > 30 | Very high | 1 | 0.2 | 1 | 0.2 | 0 | 0 | 0.0 | 0 | 0 | 0.0 | 1 | 100 | 0.2 |
| Total | | 443 | 100.0 | 90 | 20.2 | 43 | 48 | 9.7 | 41 | 46 | 9.3 | 6 | 7 | 1.4 |

TABLE 5. DISTRIBUTION OF LOW, AVERAGE AND HIGH YIELD SELECTIONS UNDER DIFFERENT RUBBER CONTENT AND YIELD VARIABILITY CLASSES

| Class | Quality | Inclusions in the top 20% selections | | Yield Class Low (<1 g $t^{-1}$ $t^{-1}$) | | Average (>1 & <2 g $t^{-1}$ $t^{-1}$) | | High (> 2 g $t^{-1}$ $t^{-1}$) | |
|---|---|---|---|---|---|---|---|---|---|
| | | No. | % | No. | % | No. | % | No. | % |
| Rubber content (%) | | | | | | | | | |
| < 20 | Unacceptable | 9 | 10.0 | 4 | 44.4 | 4 | 44.4 | 1 | 11.1 |
| 20 - 25 | Acceptable | 16 | 17.8 | 2 | 12.5 | 9 | 56.3 | 5 | 31.3 |
| 25 - 30 | Good | 24 | 26.7 | 11 | 45.8 | 13 | 54.2 | 0 | 0.0 |
| >30 | Excellent | 41 | 45.6 | 26 | 63.4 | 15 | 36.6 | 0 | 0.0 |
| Total | | 90 | – | 43 | 47.8 | 41 | 45.6 | 6 | 6.7 |
| Yield variability (%) | | | | | | | | | |
| < 20 | Low | 2 | 2.2 | 2 | 100.0 | 0 | 0.0 | 0 | 0.0 |
| 20 - 30 | Moderate | 10 | 11.1 | 5 | 50.0 | 4 | 40.0 | 1 | 10.0 |
| 30 - 40 | High | 32 | 35.6 | 18 | 56.3 | 13 | 40.6 | 1 | 3.1 |
| >40 | Very high | 46 | 51.1 | 18 | 39.1 | 24 | 52.2 | 4 | 8.7 |
| Total | | 90 | – | 43 | 47.8 | 41 | 45.6 | 6 | 6.7 |

TABLE 6. DISTRIBUTION OF LOW, AVERAGE AND HIGH YIELD SELECTIONS AMONG WW AND HS PROGENIES

| Yield Class | Type of progeny WW | | HS | |
|---|---|---|---|---|
| | No. | % of total | No. | % of total |
| Low | 15 | 40 | 27 | 53 |
| Average | 18 | 49 | 22 | 43 |
| High | 4 | 11 | 2 | 4 |
| Total | 37 | – | 51 | – |

WW = Full-sib progenies of crosses between cultivated clones
HS = Half-sib progenies

was 19.6 mL $t^{-1}$ $t^{-1}$ (PB 330 × RRII 414) while the dry rubber yield was 4.1 g $t^{-1}$ $t^{-1}$. Lowest dry rubber yield noted was 1.3 g $t^{-1}$ $t^{-1}$ (HS of PB 330). DRC in the top yielding seedlings was around 20%. Variability observed in yield of the seedlings was high in most of the cases. Bark thickness and latex vessel rows did not show much variation.

Weather conditions during test-tapping were typical of warm humid climatic zone of India. The seedlings experienced both water stress and totally stress free situations. Steady increase in variability in girth of seedlings indicated increasingly developing competition among the seedlings. Normally, test-tapping is carried out on two to two and a half year

TABLE 7. ANATOMICAL CHARACTERS OF SEEDLING PROGENIES IN NURSERY AT AGE 3

| Type of Seedling (Progeny) | No of seedlings | Total bark thickness (mm) | | | | | No. of latex vessel rows | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Min | Max | SD (+) | CV (%) | Mean | Min | Max | SD (+) | CV (%) |
| WA progenies | | | | | | | | | | | |
| RRII 105 × AC 2004 | – | – | – | – | – | – | – | – | – | – | – |
| RRII 105 × AC 2584 | 1 | 2.6 | 2.6 | 2.6 | -- | -- | 4 | 4 | 4 | -- | -- |
| RRII 105 × RO 1739 | – | – | – | – | – | – | – | – | – | – | – |
| RRII 105 × MT 1057 | 2 | 2.5 | 2.2 | 2.8 | 0.4 | 16.6 | 5 | 4 | 5 | 0.7 | 15.7 |
| RRII 414 × AC 2004 | 1 | 2.6 | 2.6 | 2.6 | – | – | 4 | 4 | 4 | – | – |
| RRII 414 × MT 2226 | 20 | 2.4 | 1.2 | 4.3 | 0.8 | 34.0 | 4 | 1 | 7 | 1.6 | 38.2 |
| RRII 429 × RO 1739 | 2 | 2.3 | 2.2 | 2.4 | 0.2 | 7.3 | 5 | 4 | 6 | 1.4 | 28.3 |
| RRII 429 × MT 1021 | 3 | 2.7 | 2.5 | 2.9 | 0.2 | 6.6 | 5 | 4 | 6 | 1.1 | 22.4 |
| RRII 429 × MT 2226 | 8 | 2.4 | 1.8 | 3.9 | 0.6 | 25.7 | 4 | 3 | 5 | 0.5 | 12.9 |
| Pooled | 37 | 2.4 | 1.2 | 4.3 | 0.7 | 27.2 | 4 | 1 | 7 | 1.3 | 29.6 |
| WW progenies | | | | | | | | | | | |
| RRII 105 × PB 330 | 4 | 3.3 | 2.3 | 3.7 | 0.7 | 20.5 | 4 | 4 | 5 | 0.6 | 14.0 |
| RRII 105 × IRCA 130 | – | – | – | – | – | – | – | – | – | – | – |
| RRII 414 × PB 330 | 11 | 2.72 | .0 | 3.8 | 0.5 | 19.7 | 5 | 4 | 7 | 1.0 | 19.4 |
| RRII 414 × RRIM 600 | – | – | – | – | – | – | – | – | – | – | – |
| RRII 429 × PB 330 | 4 | 2.0 | 1.3 | 2.9 | 0.7 | 34.3 | 4 | 1 | 6 | 2.2 | 51.4 |
| PB 330 × RRII 414 | 72 | 2.5 | 1.1 | 5.5 | 0.9 | 36.0 | 4 | 1 | 8 | 1.7 | 45.5 |
| PB 330 × RRII 429 | 55 | 2.0 | 1.1 | 3.2 | 0.5 | 25.8 | 3 | 1 | 5 | 1.2 | 44.9 |
| Pooled | 146 | 2.3 | 1.1 | 5.5 | 0.8 | 34.3 | 3 | 1 | 8 | 1.6 | 46.5 |
| Clonal half-sibs | | | | | | | | | | | |
| RRII 105 × ? | 79 | 2.7 | 1.1 | 4.4 | 0.7 | 26.2 | 4 | 1 | 8 | 1.4 | 34.6 |
| RRII 414 × ? | 64 | 2.2 | 1.0 | 4.1 | 0.6 | 27.1 | 4 | 1 | 8 | 1.5 | 36.4 |
| RRII 429 × ? | 50 | 2.2 | 1.3 | 3.7 | 0.6 | 25.6 | 4 | 1 | 8 | 1.6 | 34.9 |
| PB 330 × ? | 67 | 2.4 | 1.2 | 4.5 | 0.7 | 31.1 | 3 | 1 | 7 | 1.7 | 52.6 |
| Pooled | 260 | 2.4 | 1.0 | 4.5 | 0.7 | 28.9 | 4 | 1 | 8 | 1.6 | 40.3 |
| All pooled | 443 | 2.4 | 1.0 | 5.5 | 0.7 | 30.5 | 4 | 1 | 8 | 1.6 | 41.7 |

TABLE 8. CORRELATION BETWEEN YIELD AND OTHER ATTRIBUTES AMONG TOP 20 % SELECTIONS

| Attribute | Correlation with yield* | |
|---|---|---|
| | Latex volume | Dry rubber |
| Girth | 0.534 | 0.633 |
| Total bark thickness | 0.470 | 0.543 |
| Total latex vessel rows | 0.168 | 0.209 |
| Dry rubber content | -0.572 | -0.311 |

*N = 90

TABLE 9. GIRTH, YIELD AND RUBBER CONTENT IN THE TOP 5 PERCENT SELECTIONS (ON COMPLETION OF 35 TAPPINGS)

| Seedling Parentage | Seedling No. | Girth 'Nov -05 | Latex yield (mL $t^{-1}$ $t^{-1}$) | Rubber yield g $t^{-1}$ $t^{-1}$ | Rubber yield g $t^{-1}$ $10t^{-1}$ | CV (%) | TSC (DRC) | Mean TBT | Mean TLVR |
|---|---|---|---|---|---|---|---|---|---|
| PB 330 × RRII 414 | 704 | 34.2 | 19.6 | 4.1 | 41.4 | 43.1 | 21.1 | 5.5 | 6 |
| PB 330 × RRII 414 | 514 | 27.0 | 17.9 | 4.0 | 40.1 | 51.1 | 22.4 | 4.4 | 7 |
| PB 330 × RRII 414 | 683 | 25.0 | 11.5 | 2.4 | 23.7 | 49.7 | 20.7 | 3.9 | 4 |
| RRII 429 HS | 445 | 26.0 | 11.4 | 2.3 | 22.8 | 50.7 | 20.0 | 3.2 | 5 |
| PB 330 × RRII 414 | 690 | 25.5 | 11.4 | 2.1 | 21.0 | 34.6 | 18.4 | 3.7 | 4 |
| RRII 414 HS | 342 | 20.0 | 8.4 | 2.1 | 20.6 | 24.2 | 24.5 | 3.0 | 5 |
| RRII 414 HS | 575 | 21.1 | 6.6 | 2.0 | 19.9 | 24.6 | 30.2 | 3.0 | 6 |
| PB 330 × RRII 414 | 701 | 22.4 | 11.1 | 2.0 | 19.8 | 50.3 | 17.8 | 3.3 | 8 |
| PB 330 × RRII 414 | 712 | 27.0 | 6.2 | 1.9 | 18.9 | 58.7 | 30.4 | 3.1 | 5 |
| PB 330 × RRII 414 | 512 | 23.2 | 6.0 | 1.8 | 17.7 | 39.0 | 29.5 | 2.4 | 4 |
| PB 330 × RRII 414 | 700 | 24.8 | 4.7 | 1.7 | 16.8 | 66.9 | 36.2 | 4.3 | 6 |
| RRII 429 × PB 330 | 199 | 17.0 | 4.6 | 1.6 | 16.0 | 26.9 | 34.8 | 2.9 | 5 |
| PB 330 HS | 844 | 25.0 | 6.6 | 1.6 | 16.0 | 35.0 | 24.3 | 4.1 | 7 |
| RRII 414 × PB 330 | 477 | 24.3 | 6.9 | 1.5 | 15.5 | 50.4 | 22.3 | 3.1 | 7 |
| PB 330 HS | 822 | 19.2 | 5.3 | 1.5 | 15.4 | 58.4 | 29.2 | 2.5 | 5 |
| RRII 105 HS | 286 | 28.3 | 4.4 | 1.5 | 15.3 | 25.7 | 34.5 | 3.5 | 5 |
| RRII 414 HS | 335 | 19.8 | 9.0 | 1.5 | 15.0 | 30.5 | 16.6 | 2.6 | 5 |
| RRII 429 HS | 848 | 21.5 | 4.4 | 1.5 | 14.9 | 56.1 | 33.6 | 2.6 | 4 |
| PB 330 × RRII 414 | 638 | 23.0 | 6.6 | 1.5 | 14.7 | 55.4 | 22.5 | 2.9 | 6 |
| PB 330 × RRII 414 | 688 | 25.5 | 4.0 | 1.4 | 14.4 | 36.7 | 35.9 | 4.3 | 5 |
| PB 330 × RRII 429 | 881 | 21.5 | 4.9 | 1.4 | 13.5 | 56.5 | 27.4 | 3.2 | 4 |
| PB 330 HS | 843 | 19.0 | 4.7 | 1.3 | 13.4 | 42.6 | 28.7 | 2.2 | 6 |

TBT = Total Bark Thickness
TLVR = Total Latex Vessel Rows

old seedlings[3–7,16]. In this study it was carried out at the age of 3 years. The prospect of test-tapping at age two was thoroughly examined and decided against it because the girth of seedlings was insufficient to carry out half-spiral test tapping in most seedlings. Also, from the earlier test-tapping results it was found that in most seedlings, the yield obtained from 10 tappings was extremely low (unpublished data). In addition, the tappers expressed great difficulty in tapping because of very thin bark and lean nature of seedlings that needed supporting with the left hand and leg while tapping, resulting in strain and longer time duration for completing tapping task. Thus, it appears that test tapping at age 3 rather than at 2 was more prudent.

Mean dry rubber yield recorded for the selected seedlings was 11.1 g $t^{-1}$ $10t^{-1}$. A

few researchers have reported much lower values[4,8,9]. The differences could be due to the age and genetic potential of the seedlings. Lower values reported were for two-year-old seedlings while in the present study the values are for three-year-old seedlings. However, higher values ranging from 21.8 to 58.9 g $t^{-1}$ $10t^{-1}$ for a two and a half year old seedlings wherein the tapping system was 1/2S d/3 6d/7 and spacing was 1.8 × 1.8 m has also been reported[7]. The present study was confined to a lesser spacing of 0.6 × 0.6 m with 1/2S d/2 6d/7 system of tapping.

The presence of just one seedling among the top 20% selections from the low girth class (<15 cm) indicated that the probability of loosing a potential selection would be nil if this class was excluded from test-tapping. If it was implemented in this study, it would have lessened the task by 233 seedlings (out of 443) from test tapping thus reducing about 50% of the workload. The result that the presence of majority of high yielders among moderate to high girth classes indicate that concentration should be on this group for maximum success in juvenile selection. The distribution of high yield selections under different rubber content classes gives an indication that for better success concentration should be on the average yield class. Results from the distribution of high yield selections among full-sib and half-sib progenies indicate that half-sibs also can contribute substantially to the genetic improvement of *Hevea*. From the correlation of anatomical characters with yield it appears that bark thickness and latex vessel rows may not be of any significance in juvenile selection. Similar conclusions have also been reported[4].

Regarding the height of tapping, 15 to 20 cm appears to be the normal practice[4,5]. In this study, test-tapping was done from a height of 30 cm from the ground. On completion of 35 tappings, only half of the panel could be consumed. The remaining panel could have been sufficient enough for another 35 tappings. If the test-tapping had commenced right after the cessation of monsoon, it would have been possible to exhaust the complete panel thus enabling recording of renewed bark characteristics that is not being considered now but has significance for mature tapping. It is also worthwhile to consider test-tapping at a much higher height, say 60 cm or even 75 cm. This point is particularly important because tappers repeatedly complained that very low tapping height has a bearing on their efficiency and physical strain because of too much bending while tapping. If a tapping panel is opened at a higher level it would result in more efficiency and less cumbersome tapping. By extension of the idea it appears that if high girth seedlings from open pollinated seedling nurseries are stumped and established in selection nurseries, more progress appears possible both for selecting high yield as well as high growth.

Test-tapping at age 3 rather than at 2 appears to be more prudent because a large number of seedlings of girth up to 15 cm can be excluded from tapping with almost nil probability of loosing a potential genotype. This can reduce the burden of test-tapping substantially, hence more stringent and worthwhile juvenile selection can be practised. Collecting yield data in terms of latex volume can result in more accurate yield recording. In addition, the latex can be used for determining rubber content as well as biochemical and physiological determinants of yield that can further boost the probability of potential selections. The selection of seedlings giving weightage to DRC can result in eliminating very low DRC seedlings in the juvenile stage itself. For maximum genetic gain in juvenile selection, concentration should be on the moderate to high girth class and average yield class seedlings. Substantial progress appears possible, both for selecting high yield as well

as high growth, from half-sib progenies if they are stumped and established in selection nurseries. It appears that bark thickness and latex vessel rows may not be of any significance in juvenile selection.

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