Growth Studies in Hevea Brasiliensis I. Growth Analysis up to Seven Years After Budgrafting

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Growth of budded trees of two clones of Hevea brasiliensis *from nine months to nearly seven years of age was studied. The relative growth rates and net assimilation rates declined at each successive sampling interval. In contrast, however, leaf area and leaf weight ratios remained relatively constant for the first three years but were declining rapidly by the fifth year.*

Leaf area index of the stand reached a maximum of 5.8 by the time the canopy closed over. Changes in the rate of dry matter production paralleled those of leaf area index; the maximum rate being 35.5 tonnes/hectare/year. At 81 months after budding, total dry matter accumulation reached 138 tonnes/hectare.

Levels of the various growth parameters were compared with those recorded for other species, particularly tropical trees. Possible benefits from applying the results of growth analysis to rubber tree culture were also considered.

Analyses of growth have been made for several annual plants in a temperate environment and the performance of species such as tomato, sunflower and maize has been studied over a wide range of conditions including tropical climates (NJOKU, 1959). Apart from sugar-cane and cotton, however, tropical and sub-tropical species have not received much attention. There have been few attempts to analyse the growth of trees in any environment.

The most intensive studies on trees made to-date have been on *Pinus sylvestris* (RUTTER, 1957 and OVINGTON, 1957) and apple rootstocks (VYVYAN, 1957), all in England. Some investigations have also been carried out on *Theobroma cacao* (GOODALL, 1950) and *Trema guineensis* (COOMBE, 1960), but both workers confined their attention to growth in relatively young seedlings (up to 30 and 16 weeks respectively); thus their findings give little indication of parameters which determine growth during the major part of the active period. The only detailed study of the growth parameters of a large tropical plant so far has been made by REES and TINKER (1963) on oil palms (*Elaeis guineensis*), both in nursery culture up to six months of age and as a plantation crop in the age range of 7 to 22 years.

Growth of *Hevea brasiliensis* under plantation conditions, before and during tapping was investigated by the author. The present data, concerned only with the pre-tapping years but including the period when the canopy of the trees completely closes over, are among the few available on growth in tropical trees.

EXPERIMENTAL METHODS

Clones RRIM 501 and RRIM 513, both extensively budgrafted in Malaysia, were used in the study. They were planted at a spacing of 30′ × 8′ in adjacent blocks of five acres, situated on a gently sloping area of deep sandy clay loam. The early cultural details have already been described (TEMPLETON, 1961). The clones differ in growth characteristics: the canopy of RRIM 513 develops at a height lower than that of RRIM 501; it is also wider and less upright in the early years of growth with heavier branching and more dense foliage. Growth of RRIM 501 was distinctly more vigorous in the first year after budgrafting, but disparity in the rate of growth between the two clones largely disappeared by the second year.

Complete trees were sampled for total dry weight and leaf area determinations at 9, 15, 21, 27, 39, 55 (RRIM 513 only), 63 (RRIM 501

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only) and 81 (RRIM 501 only) months after budding; they remained untapped throughout this period. The samplings were made in June or January, (except for a sampling in May at 55 months), when trees were not noticeably in refoliation or defoliation. Trees for sampling were selected at random but the choice was confined to those growing at the original planting density of about 180 trees per acre—that is, trees adjacent to vacant points resulting from previous samplings or natural causes were rejected. In most cases, 9 or 10 trees of each clone were sampled on each occasion.

The operation at each sampling was to fell the trees at the stock/scion union, separate the shoot into its three major morphological units of trunk, branches and leaves and divide the branches into brown and green wood (selected on general appearances). Leaves were sub-sampled for determinations of leaf area and lamina/petiole ratio. The tap and lateral roots were excavated on the same day except on the last two sampling occasions involving large trees when the root system was dealt with the next day.

Total dry weight of trees was derived from the percentage dry weights of samples of all these parts dried to constant weight at 80°C.

Although it was comparatively easy to extract all the tap root from the soil, complete recovery of the lateral root system was not attempted partly due to the difficulty but also because the weight of the large woody lateral roots was large enough to ignore the weight of fibrous roots. Major laterals were exposed at their source (almost invariably in a whorl within 30 cm of the soil surface) and traced until their diameter had diminished to about 2 mm. Beyond this size the roots were too fragile for recovery by this method. For practical reasons, roots were recovered at each sampling from only 5 of the 10 trees after 39 months of age.

The leaf disc method was used to estimate the total leaf area. Preliminary tests indicated that estimates obtained from leaf disc and planimeter methods were in close agreement (differences of 1% or less); hence the former was adopted as it was less laborious. About 400 leaf discs of known area ($4.69 cm^2$) were punched at random with a cork-borer from a sub-sample of leaf laminae of all sizes, only the discs excised entirely from within the margins of a leaf being retained. Discs and the remaining parts were dried to constant weight in order to determine the ratio of leaf disc area to leaf disc weight. The total leaf area of the tree was estimated from this ratio and from the total leaf dry weight.

From the data of dry weight and leaf area it was possible to calculate the relative growth rates, leaf area and leaf weight ratios, and net assimilation rates of the trees, the total dry matter of the stand and its rate of production and to establish changes in the levels of these parameters with age in each clone.

Under conditions of destructive plant sampling, it is important that estimates of growth involving rate concepts for successive intervals of time should be based on independent data for each sampling occasion. If weights sampled for one occasion deviate widely from the long-term trend of the data, estimates of rate for the intervals involving such figures may be greatly distorted, obscuring real growth trends. In the present work, the trunk girth of each tree was recorded for all sampling times prior to its actual destruction for dry weight determinations. From the data, a highly significant regression relationship has been established over the experimental period between the girth of the trunk 60 inches above the budgraft union and the total dry weight of the shoot for both clones. SHORROCKS *et al.* (1965) reported similarly significant regression relationships for many clones of *Hevea*, and derived also a general equation for studies on the evaluation of growth. Further highly significant regressions between the tap root, lateral roots and stock stem (the stem base of the original seedling remaining after the establishment of a bud-grafted tree) on the one hand and the shoot dry weight on the other have also been established. Using these four equations, the total dry weight for individual trees at any sampling time was estimated and parameters of growth rate derived.

Separate regressions for the major morphological units of shoot and roots from which a total tree dry weight was derived were used instead of a single regression of total plant dry weight to girth because of the much higher statistical significance. The inferiority of the regression equations based on total dry weight was due to the abnormal shoot/root ratios and small girths of young buddings at the early sampling occasions, as a consequence of budding large stocks more than one year old. In using calculated tree weights at various ages, it was necessary to adjust the total leaf area data, and for this purpose, a highly significant regression of leaf area on total dry shoot weight was used for occasions up to 63 months of age. Beyond this, however, there was a marked decrease in the rate of leaf growth and for the final interval up to 81 months a much less significant equation had to be used. All regression equations used are listed in *Table 1* along with correlation coefficients and the standard errors of the regression coefficients.

TABLE 1. REGRESSION EQUATIONS USED FOR ADJUSTING PRIMARY DATA ON ANALYSES OF GROWTH OF TWO CLONES OF *HEVEA BRASILIENSIS*

Morphological components	Clone RRIM 501	Clone RRIM 513
Total Shoot Y = $\log_e$ total shoot (kg) X = $\log_e$ girth (cm)	Y = 2.923X — 2.833 S_b 0.0203 r = 0.999**	Y = 2.969X — 2.823 S_b = 0.0302 r = 0.998**
Tap Root Y = $\log_e$ tap root (kg) X = $\log_e$ total shoot (kg)	Y = 0.550X —. 0.042 S_b = 0.0194 r = 0.978**	Y = 0.628X — 0.129 S_b = 0.0299 r = 0.961**
Lateral Roots Y = $\log_e$ lateral root .10^2 for RRIM 501 (kg) Y = $\log_e$ lateral root for RRIM 513 (kg) X = $\log_e$ total shoot (kg)	Y = 1.033X + 0.717 S_b = 0.0383 r = 0.977**	Y = 1.156X – 1.559 S_b = 0.0981 r = 0.907**
Stock Stem Y = $\log_e$ stock stem × 10 (kg) X = $\log_e$ total shoot (kg)	Y = 0.486X + 0.475 S_b = 0.0328 r = 0.925**	Y = 0.487X + 0.003 S_b = 0.0264 r = 0.939**
Leaf Area Y = $\log_e$ leaf area (cm^2) X = $\log_e$ total shoot (g)	*up to 63 months* Y = 0.842X + 1.887 S_b = 0.0159 r = 0.992** *63–81 months only* Y = 0.848 + 4.191 S_b = 0.3378 r = 0.664*	Y = 0.798X + 2.087 S_b = 0.0195 r = 0.982**

S_b = Standard error of regression coefficient.
r = Correlation coefficient.
* Minimum significant difference (p=0.05).
** Minimum significant difference (p=0.01).

RESULTS

Dry Matter Production Per Tree

The average total dry weight per tree at each sampling occasion is given in *Table 2* with the average girth of the trunk at 60 inches above the union and the mean girth increment per month. *Figure 1* shows the log. of the weight over the same period for RRIM 501—the curve for RRIM 513 would be almost superimposed and therefore is not given. In both clones the total dry weight appoximately increased exponentially up to 39 months—the weight doubling about every six months. Later this rate was not maintained. The total dry weight of RRIM 501 exceeded 300 kg per tree within seven years.

Average monthly increments in girth show similar trends in both clones. The values were steady between 9 and 21 months, maximal between 27 and 39 months and fell thereafter.

Although the weight and girth figures for the two clones were similar for all coincident sampling occasions, trees of RRIM 513 showed a consistently greater weight and a lesser girth than those of RRIM 501.

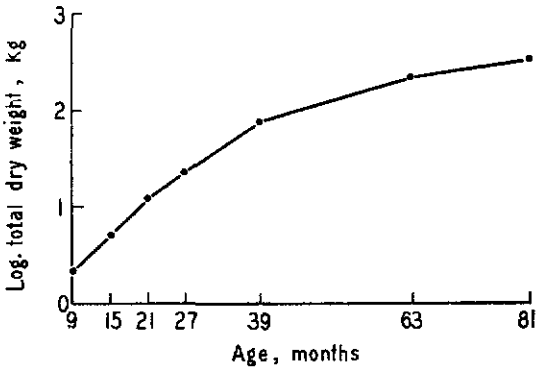

Figure 1. Increases in log. total dry weight in RRIM 501 from 9 to 81 months after budding.

Relative Growth Rate/Tree

Relative growth rate (RGR) expresses the rate of gain in tree dry weight per unit time. It is the product of two component parameters, the net assimilation rate (NAR) and the leaf area ratio (LAR).

RGR's for both clones, expressed as g/g/week $\times 10^3$ are shown in *Figure 2.* For one-year-old

TABLE 2. AVERAGE TOTAL DRY WEIGHT PER TREE, TRUNK GIRTHS AND MONTHLY GIRTH INCREMENTS FOR SUCCESSIVE SAMPLING OCCASIONS

Age of buddings (months)	Total dry weight (kg) per tree		Girth (cm)		Average monthly girth increment between sampling occasions (cm)	
	RRIM 501	RRIM 513	RRIM 501	RRIM 513	RRIM 501	RRIM 513
9	2.20	2.35	8.7	7.8		
					0.8	0.8
15	5.15	4.80	13.5	12.7		
					0.8	0.8
21	10.80	11.65	18.1	17.6		
					0.95	0.9
27	22.20	25.60	23.8	23.2		
					1.1	1.0
39	74.75	77.40	36.9	35.2		
						0.65
55	—	151.45	—	45.8		
					0.75	
63	213.40	—	54.8	—		
					0.5	
81	312.45	—	63.7	—		

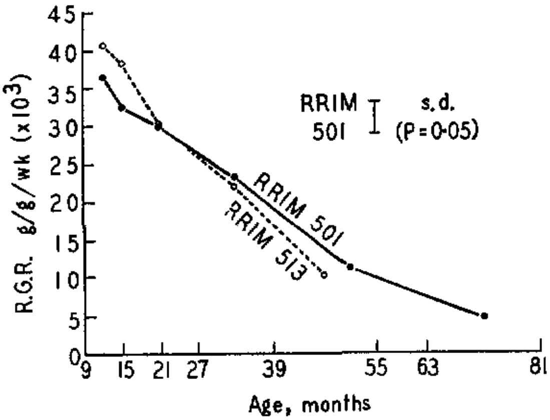

Figure 2. Changes in relative growth rate from 9 to 55 months (RRIM 513) and 81 months (RRIM 501) after budding.

buddings, the growth rate was between 3.5 and 4% per week but it declined steadily later, the estimate for RRIM 501 at 81 months being only about one-seventh the rate at 15 months.

The differences between most harvest intervals were highly significant for RRIM 501. The levels of significance could not be obtained for RRIM 513 because some individual tree girth records for early sampling occasions were lost—however, in these cases means of the girth data were used to calculate the weight/girth regressions and interval RGR's.

Table 3 compares RGR's for shoot and whole trees. Values for shoot were about 30% higher than that for the whole tree until 21 months after budgrafting; later they converged and were virtually the same from the fifth year. This finding is of practical importance in view of the difficulties of root excavation in all but small trees.

TABLE 3. RELATIVE GROWTH RATES (G/G/WEEK 10^3) OF TOTAL TREE AND TOTAL SHOOT IN CLONE RRIM 501

Age of trees (months)	RGR total tree wt.	RGR total shoot wt.	Difference (%)
9—15	36.5	47.7	31
9—21	32.8	42.6	30
15—27	30.0	33.7	12
27—39	23.3	25.3	9
39—63	11.3	11.9	5
63—81	4.8	4.9	2

Net Assimilation Rate

Net assimilation rate (NAR) relating the gain in dry weight per unit time to unit leaf surface expresses the net balance of photosynthetic and respiratory processes. *Figure 3* illustrates the changes in NAR of the two clones over successive age intervals. As with RGR, the level steadily declined throughout the period of observation. For RRIM 501, the rate fell from 0.0034 to 0.0099 g/cm²/week. Values for RRIM 513 were mostly lower than those of RRIM 501 at similar ages ,but the differences were small in relation to the errors of estimation indirectly indicated by the magnitude of the 5% least significant differences in the related parameters of RGR and leaf area ratio (*Figures 2* and *4* respectively).

Leaf Weight and Leaf Area Ratios

These ratios (LWR and LAR) are measures of leafiness and express the ratio of total leaf weight and total leaf area to total tree weight

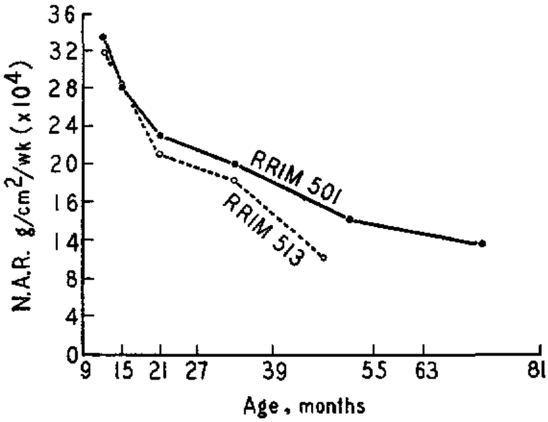

Figure 3. Changes in net assimilation rate from 9 to 55 months (RRIM 513) and 81 months (RRIM 501) after budding.

respectively. LAR is the product of $LWR = \frac{LW}{W}$ and a specific leaf factor $\frac{LA}{LW}$

$$\text{thus } LAR = \frac{LW}{W} \times \frac{LA}{LW} = \frac{LA}{W}$$

where LW is total leaf weight,
LA is total leaf area,
and W is total plant dry weight.

For the early harvests, only leaf weight data was collected, the leaf areas being calculated by an average specific leaf factor of 116 cm^2/g derived from numerous determinations. In all estimates of LWR, the weight of petioles was excluded.

The progression of LWR with age was similar in both clones (*Figure 4*). Up to 39 months, the changes in levels were not significant although a peak was noticed at 27 months. There was a sharp decline in the ratio at later sampling times.

Values of the leaf area ratio (LAR) for the two clones at successive harvests are shown in *Figure 5*. As with LWR, values fluctuated only over a narrow range up to 39 months of age, with no significant differences ($p = 0.05$). The average LAR for this period was approximately 12 cm^2/g in both clones. Therefore there were clearly no changes in leafiness which could have contributed substantially to the significant decline in RGR during this time. Subsequently, the ratio declined sharply and reached 4 cm^2/g in RRIM 501 at 81 months.

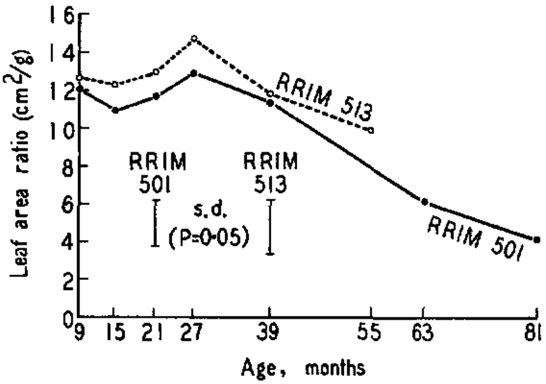

Figure 5. Changes in leaf area ratio from 9 to 55 months (RRIM 513) and 81 months (RRIM 501) after budding.

Leaf Area Index

Leaf area index (LAI) is the ratio of total leaf area (LA) to ground area occupied—calculated, in this instance, for a stand of trees of unit area. *Figure 6* shows that LAI increased rapidly in both clones from very low initial values. In RRIM 501, the index levelled off at about 5.8—the ceiling value for RRIM 513 was not ascertained. Data in *Table 4* indicate the magnitude

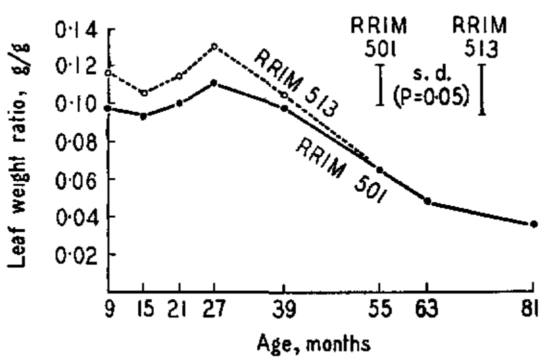

Figure 4. Changes in leaf weight ratio from 9 to 55 months (RRIM 513) and 81 months (RRIM 501) after budding.

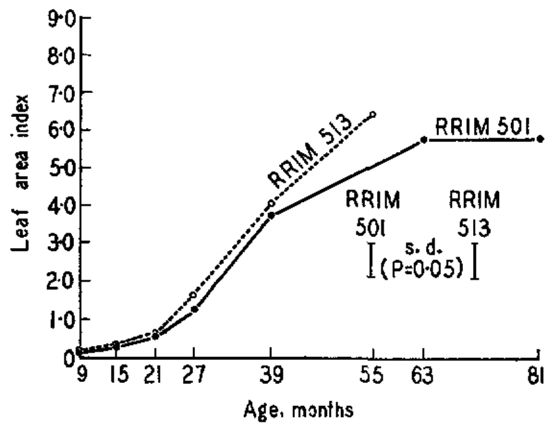

Figure 6. Changes in leaf area index from 9 to 55 months (RRIM 513) and 81 months (RRIM 501) after budding.

of the total leaf area of trees when at their maximum LAI.

In a young plantation, where a large proportion of the light is not intercepted since much of the ground surface is outside the spread of tree canopies, it is useful to consider the total ground area within the periphery of the canopies in relation to the total leaf area. This ratio was calculated for RRIM 501 using estimates of the maximum radial spread of canopies of individual trees at various ages (*Table 4*). Less than half the ground area fell under the vertical projection of canopies in the period up to 27 months of age, and only after about 5 years was a fairly complete cover achieved. Inspection of the ratios of total leaf area per tree to the vertically projected ground area beneath reveals however that a ceiling value similar to that for LAI was attained before the maximum LAI. It would seem, therefore, that by about the age of four years the area of leaf surface within a large portion of the canopy had already reached a maximum governed by the quantity of light available to it.

Rate and Total Dry Matter Production of Stand

The rate of dry matter production per unit area of ground surface of the stand (RDMP expressed as tonnes/hectare/year) is, for any interval of time, the product of the mean NAR of the total leaf surface and the ratio of the total leaf surface to ground surface, *i.e.*, LAI. *Figure 7* shows that the rates increased rapidly up to 39 months, then rose less steeply to a peak value in RRIM 501 of 35.5 tonnes/hectare/year at between 39 and 63 months of age. Trends in RRIM 513 were similar up to 39 months; however for the 39 up to 55 month interval the rate was only 28.2 tonnes/hectare/year (not shown in figure), an effect of the very high total leaf area of the trees sampled in May at the time of peak refoliation. In the main, increasing RDMP's were a reflection of the changes in LAI as these were relatively greater than the concomtant declines in NAR (*Figures 2* and *6*).

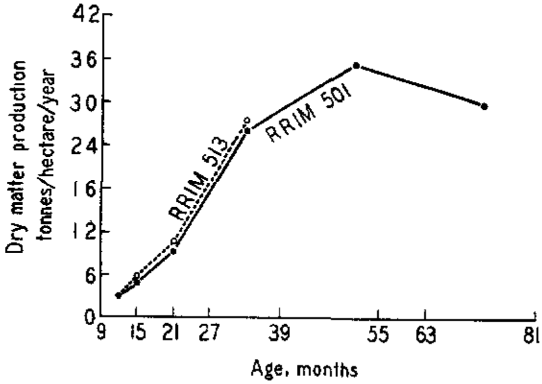

Figure 7. Changes in rate of dry matter production from 9 to 39 months (RRIM 513) and 81 months (RRIM 501) after budding.

Based on a constant 180 trees per acre, the increasing total dry matter production (DMP) of the stand, calculated by the ratio $\frac{\text{LAI}}{\text{LAR}}$ and

TABLE 4. TOTAL TREE LEAF AREAS (cm^2) FOR BOTH CLONES AND PARAMETERS OF LEAFINESS FOR RRIM 501

Age (months)	Total leaf areas (cm^2)		% ground surface vertically overlaid by canopies	Leaf area index (RRIM 501)	Ratio of canopy surface per tree to ground surface vertically underneath (RRIM 501)
	RRIM 501	RRIM 513			
9	22 700	24 100	4	0.1	—
15	57 100	58 500	20	0.3	1.3
21	126 000	150 300	33	0.6	1.7
27	286 100	374 400	46	1.3	2.8
39	842 300	913 100	66	3.7	5.7
55	—	1 453 100	—	—	—
63	1 299 000	—	93	5.8	6.2
81	1 294 600	—	99	5.8	5.8

expressed in tonnes/hectare, is shown in *Figure 8*. The curves rise slowly during the first two years and then become steeply ascending straight lines. At the time of the harvest in RRIM 501 at 81 months, there was a total dry matter accumulation of 138 tonnes/hectare.

The growth parameters of RGR, NAR and LAR measure net gains in dry matter production and so the derived parameters of RDMP and DMP express net changes. Gross productivity under field conditions would be exceedingly difficult to determine. In addition to making allowances for the natural loss of branch, leaf and root materials, it would be necessary to ascertain values of gross photosynthesis and respiration.

DISCUSSION

The period of 81 months studied here is only about one-fifth of the usual life of *Hevea* trees in commercial plantations, but it is the most interesting for analysis because it includes the period of the closing of the canopy when various parameters can be expected to exhibit major changes. Changes after the canopy closes are more gradual extensions of growth trends already established. RGR, NAR and LAR would all be expected to continue to decline gradually—as would the rate of dry matter production under the influence of the trend in NAR. In contrast, LAI, would remain near its ceiling value for many years until the onset of senescence. The author determined some parameters of leafiness in a stand of 30-year-old trees of clone AVROS 50. Although at that age LAR was down to 1.3 and LWR to 0.011, LAI was 4.9— a value comparable to that in 7-year-old trees of RRIM 501 and indicative of the maintenance of the index at a fairly constant level for most of the life of the stand.

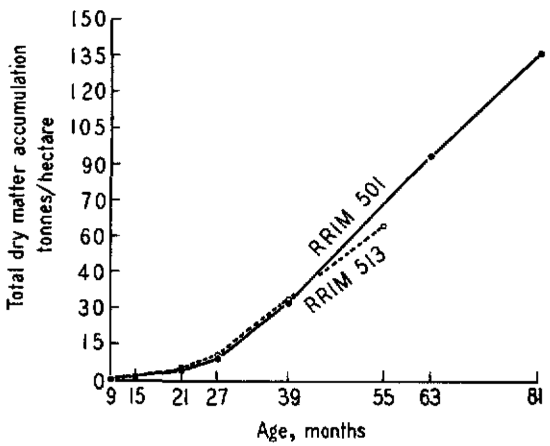

Figure 8. Changes in total dry matter accumulation from 9 to 55 months (RRIM 513) and 81 months (RRIM 501) after budding.

From *Figures 2, 3* and *4*, it was concluded that while the steady decline in RGR up to 39 months of age was the result of a progressive fall in NAR (the proportion of photosynthetic to non-photosynthetic tissues remaining fairly constant during this time), in subsequent intervals it was the effect of similar rates of decline in both NAR and LAR. The decrease in LAR at this later period reflects the increasing proportion of total plant weight comprising non-photosynthetic tissues. The decline in NAR, on the other hand, stems from the greater degree of self-shading of leaves as LAI of the stand rapidly increased during the early years of growth (*Figure 6*). More self-shading accompanied by a steepening light gradient in the canopy reduces the average photosynthetic rate per unit leaf area and hence the NAR of the trees. Without a compensatory rise in LAR, the RGR must fall.

The values recorded in these investigations for RGR in *Hevea* are low compared with estimates for many species, especially herbs, growing in other environments. Comparing values for the few tree species for which published data are available, it was found that levels in the first years of growth are similar to those recorded for temperate species. Thus, the maximum value obtained for RRIM 501 of 0.037 g/g/week between 9 and 15 months of age is comparable to the 0.035 g/g/week for one to two-year-old apple rootstocks (VYVYAN, 1957) but lower than the 0.083 g/g/week recorded by OVINGTON (1957) for three-year-old trees of *Pinus sylvestris*. MULLER AND NIELSON (1965) obtained an average RGR of about 0.008 g/g/week for virgin tropical rain forest (excluding roots)—a value of the same order as that for *Hevea* in the age interval 5 to 7 years (0.005 g/g/week). COOMBE (1960) recorded an RGR of 0.37 g/g/week for seedling plants of *Trema guineensis* (a tropical tree) up to 16 weeks of age.

NAR and LAR values for *Hevea* are generally low in comparison with those of many non-tropical herbaceous species, among which an NAR as high as 0.02 g/cm^2/week and an LAR of 198 cm^2/g have been recorded for *Helianthus annuus* (WILSON, 1966). However, the levels of NAR in *Hevea* are relatively higher than values recorded for tree species (*Table 5*).

It is concluded that the low RGR in *Hevea*, although influenced by many internal and external factors, is basically the result of a relatively low LAR, the NAR being relatively high. Vyvyan reached a similar conclusion from studies of growth in apple rootstocks and suggested that factors determining the distribution of assimilates between various organs may be involved. In *Hevea* trees, however, low LAR values were inevitable in the early months after budding, with a small scion on the root system of a one-year-old stock; again, in the 9 to 15 month interval, LAR would have been artificially depressed by the pruning of all branches growing from the main stem below about 10 feet in height to produce an unbranched trunk for future tapping. Intrinsic values of LAR in *Hevea* might well be higher. *Table 6* contains average RGR, NAR and LAR values for four clones recorded by the author in 1½ to 2-year-old trees which had originated as rooted stem cuttings and had been allowed to develop without any pruning. The average LAR values are more than 50% higher in the rooted cuttings than for the buddings, and the related value of RGR is markedly higher, despite a lower NAR.

The maximum RDMP for *Hevea* of 35.5 tonnes/hectare/year falls in the upper range of values recorded for stands of other tropical trees. Although WECK (1957) estimated a rate of 54 to 69 tonnes/hectare/year for some species of tropical rain forest trees, DAWKINS (1967), working from data of wood volume production in natural stands, concludes that in a closed

TABLE 5. SOME VALUES OF NET ASSIMILATION RATE FOR TREE SPECIES

Species	NAR (g/cm^2/week)	Age of plant	Reference
Trema guineensis	0.0014	seedlings	COOMBE (1960)
Pinus sylvestris	0.0016	3 to 7 years	RUTTER (1957)
Elaeis guineensis	0.0010	up to 6 months	REES and TINKER (1963)
Citrus sp.	0.0025	seedlings	MONSELISTER (1951)
Hevea brasiliensis	0.0034	9—15 months	
	0.0018	3 1/3 years	

TABLE 6. PARAMETERS OF GROWTH OF BUDDINGS AND ROOTED CUTTINGS OF SIMILAR AGE

Material	RGR	NAR	LAR
Buddings	30.0 g/g/week	23.1×10^4 g/cm^2/week	12.5 cm^2/g
Rooted cuttings	39.5 g/g/week	18.7×10^4 g/cm^2/week	19.4 cm^2/g

equatorial forest on lowland sites maximum production is only about 16 tonnes/hectare/year with 4 to 9 tonnes being common. However for indigenous or introduced conifers and eucalypts at higher altitudes in the same zone, he notes that forestry production is usually between 13 and 40 tonnes/hectare with up to 50 tonnes from exceptional eucalypt sites. Rees and Tinker recorded a rate of 30.3 tonnes/hectare/year for six-month-old oil palms in a nursery, and 19.5 tonnes/hectare/year for palms aged 17–22 years. Generally these values of RDMP in the tropics are in excess of those recorded for trees in temperate regions; as for example, 19 tonnes/hectare/year for *Pinus sylvestris* (OVINGTON) and 8 tonnes/hectare/year (excluding roots) for a 20-year-old stand of *Betula alba* (OVINGTON AND MADGWICK, 1959).

The LAI increased steadily up to the time the canopy closed over and then assumed a nearly constant value of about 5.8. LAI maxima vary with species. In temperate crop plants including grasses, maxima range from less than 5 to over 20. Few LAI data are available for trees. Rutter estimated 3.3 for *Pinus;* Ovington and Madgwick found up to 6.5 for *Betula alba;* Rees and Tinker found a peak of 5.6 with oil palms at 20 years. SHORROCKS (1965) obtained for rubber trees of clone RRIM 501 values mostly similar to those reported in this paper—however, for 10 and 24-year-old trees, he obtained LAI values as high as 14 and considered that even higher values could be expected in well-grown stands. It will be noted that these high estimates involved the use of a factor of 150.3 cm^2/g of laminae as compared to the 116 cm^2/g used here.

Whereas the commercial yield of many crops absorbs a large proportion of the total dry matter production, latex extraction from *Hevea* involves only a small proportion of the total. About 5 kg of total solids may be removed in the latex annually during the early years of tapping high yielding clones thus representing only about $2\frac{1}{2}\%$ of the annual dry matter accuumlation. In later years, when the yield may have more than doubled but the rate of tree growth has fallen substantially, exploitation could remove a much higher proportion.

Principles evolved from the study of population productivity show that the maximum partition of carbon substrates to latex production should occur when the most active areas of growth in the tree have reached a fairly steady state and when there is a maximum interception of light by the canopy, i.e. when LAI is about 6. Ideally then, trees should be tappable from the time the canopy closes over. Economic considerations dictate that growth during immaturity should be maximised. From the view point of growth analysis, maximum growth advantages will accrue when LAI, and hence RDMP, of the stand increase throughout this period, peak values coinciding with the attainment of tappable size.

It is seen from *Figure 7* that, in both RRIM 501 and 513 growing at a density of 180 trees per acre, the maximum values of RDMP occurred at about 4 years of age—one year before the trees were ready for tapping. *Figure 6* provides evidence that maximum LAI was attained too early. The relationship of LAI to the rate of growth in girth may be gauged from *Table 2*, in which the average monthly increments of girth for the intervals between sampling occasions are shown. Girth rate shows consistent small increases up to 39 months of age, then declines steeply. Had the girth rate been maintained at its earlier levels up to the time the trees reached tappable size, it is estimated that they would have become tappable up to seven months earlier. Obviously the time at which the canopy of a stand closes over depends on the density of planting. Promoting more rapid attainment of maturity through reduction in stand per acre has the effect of lowering the potential total yield. This is an economic problem. The current move to lower planting densities to about 140 trees per acre, instead of the 180 to 200 trees per acre until recently favoured, should hasten tapping maturity as it is in harmony with the concepts of growth control.

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