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Effect of Interstock on Dry Matter Production and Growth Analysis of Hevea brasiliensis (*Muell. Arg.*)

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The influence of five interstock clones of contrasting vigour on dry matter production and distribution of three Hevea brasiliensis *clones grown in the ground nursery over a two-year period was studied. Results obtained after one year of planting indicate that the influence of interstock and scion upon various aspects of growth were generally found to be additive with some showing significant interaction between scion and interstock.*

The influence of interstock on scion growth was related to the inherent vigour characteristic of the interstock clones. Trees on vigorous interstock (TR 3702 and RRIM 613) produced more dry matter in the above-ground plant parts than those on less vigorous interstocks (H. spruceana *and RRIM 600). Leaf area, whole tree dry weight, mean relative growth rate and mean net assimilation rate followed a similar pattern. In these composite trees, it appears that there is competition for photosynthate between scion stem and roots with vigorous interstocks being able to divert more photosynthate to scion stem than to roots. The significance of these findings are discussed.*

Hevea tree is propagated vegetatively by grafting suitable high yielding clones onto seedling rootstocks. Rootstock therefore forms an important component of the composite tree as it has inherent ability to improve tree growth and productivity[1]. However, currently, the availability of suitable rootstocks with known potential such as PB 5/51, RRIM 623 and GT1 remain a major concern among rubber growers because these clones are no longer planted large scale nation-wide. Interstock represents a potential method to overcome this problem; since in apples, it has been shown that certain interstock such as M9 produced similar effects as the rootstock on growth and yield of scion[2-4]. Hence, interstock may present an alternative approach to obtaining more productive trees in the absence of clonal rootstocks.

In apples, research on the growth patterns and physiology of composite trees is well documented[5-7] although in other temperate fruit trees such as cherry, citrus, pears and plums this has not been intensively studied[8-12]. In apples, interstock is used mainly to control tree size. This is possible by using dwarfing interstock which reduced many growth parameters such as scion height, girth, leaf area, dry matter production

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and relative growth rate resulting in smaller tree size than given by invigorating interstocks[4,13,14].

In *Hevea*, early experiments on the use of interstock were aimed at reducing the variability due to illegitimate seedling rootstocks[15]. Ostendorf[16] in his study on three-part-trees in which the trunk can be regarded as long 'interstock', reported that the use of vigorous *Hevea brasiliensis* clones as 'interstock' did not improve growth of scion of *Hevea* species with reduced growth potential such as *H. spruceana*, *H. guianensis* and *H. collins*. In more recent years, Leong and Yoon[17] have reported that scion growth was substantially reduced when interstock with reduced growth potential such as *H. brasiliensis* 'Dwarf' clone and *H. spruceana* were used. It is obvious from these reports that detailed studies of the growth patterns of these composite trees in *Hevea* are lacking.

This study evaluates the influence of five interstock clones of contrasting vigour on production and distribution of dry matter to various plant parts in order to provide a better understanding of the physiological basis for growth differences of the composite tree. Some of the results have been communicated in an abstract form[18].

MATERIALS AND METHODS

Interstock plants were produced by grafting three scion clones (RRIM 600, RRIM 802 and PB 235) on to five interstock clones, TR 3702, PB 5/51, RRIM 613, RRIM 600 and *H. spruceana*. Both the interstock and scion clones were selected for their contrasting vigour characteristics before tapping[19–22]. *H. spruceana* was chosen because it is known to depress scion growth when used as an interstock and rootstock[17, 23]. All interstocks were 20 cm in length. The rootstock was RRIM 600 monoclonal seedling. Controls were plants with the same scion and interstock clones.

The interstock plants at first and second-whorl stage were planted in 1982 in the ground nursery at the RRIM Experimental Station, Sungai Buloh, Selangor in a triangular pattern spaced out at 90 cm x 90 cm. The experiment, consisting of 18 treatments, were laid out in a completely randomised design within each harvest block. The plants were harvested for the determination of dry matter production at the time of planting and thereafter at half-yearly intervals over a period of two years to give a total of five harvests. The total number of plants per treatment at each harvest ranged from five to ten. At each harvest, dry weights of various plant components (laminae, petiole, scion and interstocks stem and roots) were determined after drying for 48 h at 85°C. For leaf area (LA) determination, leaf discs (2.7 cm^2 area) were sampled from a total of 4–15 leaflets per plant. The total LA of a tree was estimated based on the formulae given by Watson[24]. Standard growth analysis parameters such as leaf area ratio (LAR), specific leaf area (SLA), mean net assimilation rate (NAR) and mean relative growth rate (RGR) of whole plants were calculated from data of LA and dry weights of leaf and whole plant according to the formulae and assumptions given by Briggs *et al.*[25], Fisher[26], Williams[27] and Redford[28].

Data Analysis

All data were subjected to a two-way analysis of variance to test for the scion and interstock main effects and their interaction. F statistics at P≤0.05 was used for test of significance; least significant difference (LSD) at the same probability level was used for comparison of individual means.

RESULTS

In the present study, many parameters of plant growth were affected by interstock only at one year after planting (*Appendix 1*). Interactions between scion and interstock clone were detected at or after the first year for some of these variables.

Leaf Area and Dry Matter Production

Leaf area and biomass of various plant parts are shown in *Table 1* and *Figures 1–5*. At one year after planting, trees on TR 3702, RRIM 613 and PB 5/51 interstocks had comparable LA and dry weights of laminae, petiole and scion stem; these were significantly higher than those produced by *H. spruceana* interstocks (*Table 1*). Leaf area of trees on vigorous interstocks were about 21% to 23% larger than the control while trees on *H. spruceana* interstock had comparable LA to the control. TR 3702, RRIM 613 and PB 5/51 interstocks also produced 6% to 22% larger dry weight of scion stem than the control. In contrast, trees on *H. spruceana* interstock had the poorest growth as their scion stem dry weights were only 77% of the control.

After 1.5 years of planting, the effect of interstock on LA and dry weights of petiole, scion stem and whole tree depended on scion clone since there was a significant interaction between these two effects (*Appendix 1*). For LA, the (scion × interstock) interaction appears to have arisen from the lack of interstock influence on LA of RRIM 802 scion (*Figure 1*). However, PB 235 scion clone had significantly higher LA on *H. spruceana* and RRIM 613 interstocks than on TR 3702 and RRIM 600 interstocks. For

TABLE 1 EFFECT OF INTERSTOCK ON LEAF AREA, LEAF AREA RATIO AND DRY WEIGHT OF VARIOUS PLANT PARTS AT ONE YEAR AFTER PLANTING [a]

Interstock clone	Leaf area	Dry weight (g)				
	$(cm)^2$	Laminae	Petiole	Scion stem	Whole tree	Leaf area ratio
TR 3702	194	174	41	555	1363	14 6
RRIM 613	194	173	39	529	1345	15.2
PB 5/51	190	175	39	470	1208	16 4
Control [#]	157	137	34	421	1113	14 9
H spruceana	152	132	30	342	960	16.5
RRIM 600	151	134	32	421	1132	13.6
Mean	173	154	36	460	1193	15.2
LSD (P<0.05)	36	31	7	96	211	1.6
Level of probability	*	*	**	***	**	**

[a] Each figure is an average of 3 scion clones

[#]. Control consists of plants in which the interstock and scion are of the same clone (RRIM 600, RRIM 802 or PB 235)

*, **, ***. F - test significant at P<0.05, 0.01 or 0.001, respectively

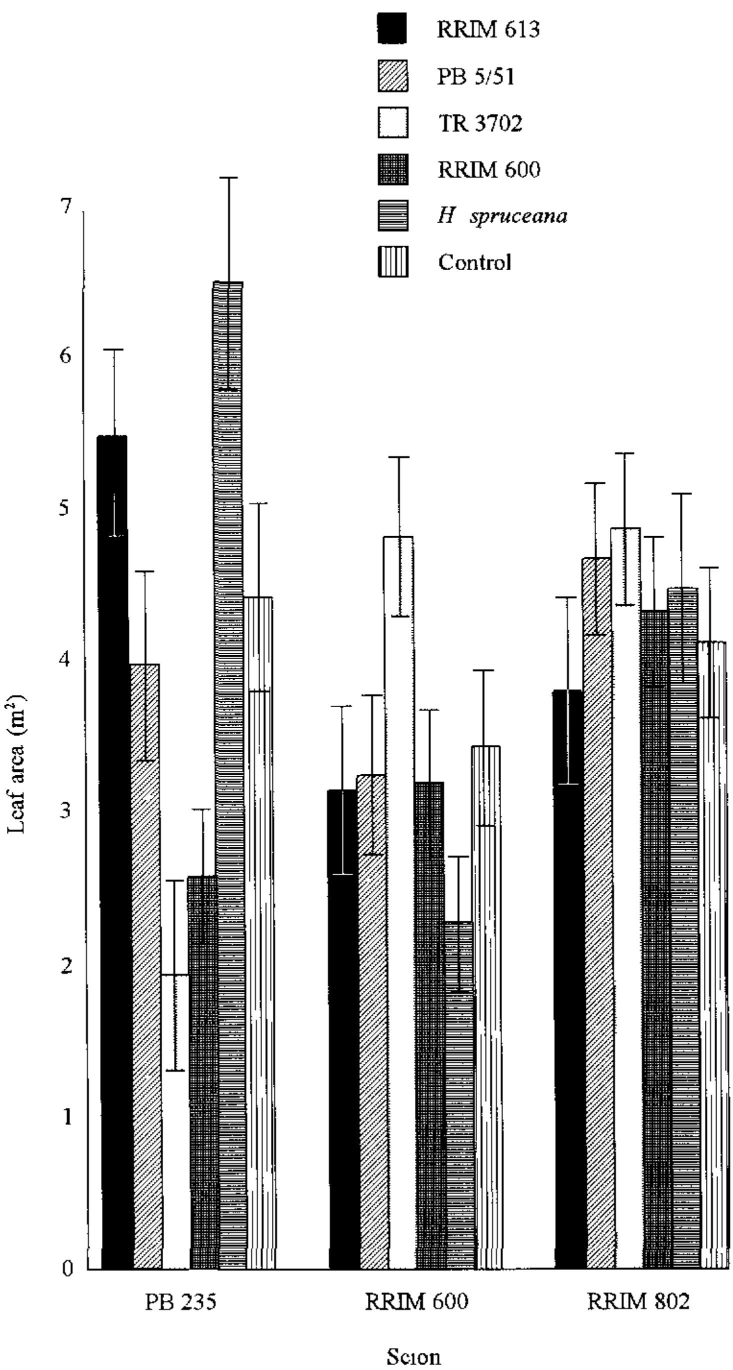

Figure 1 Effect of interstock clone on leaf area at 1 5 years after planting (Vertical lines represent SE associated with each combination mean)

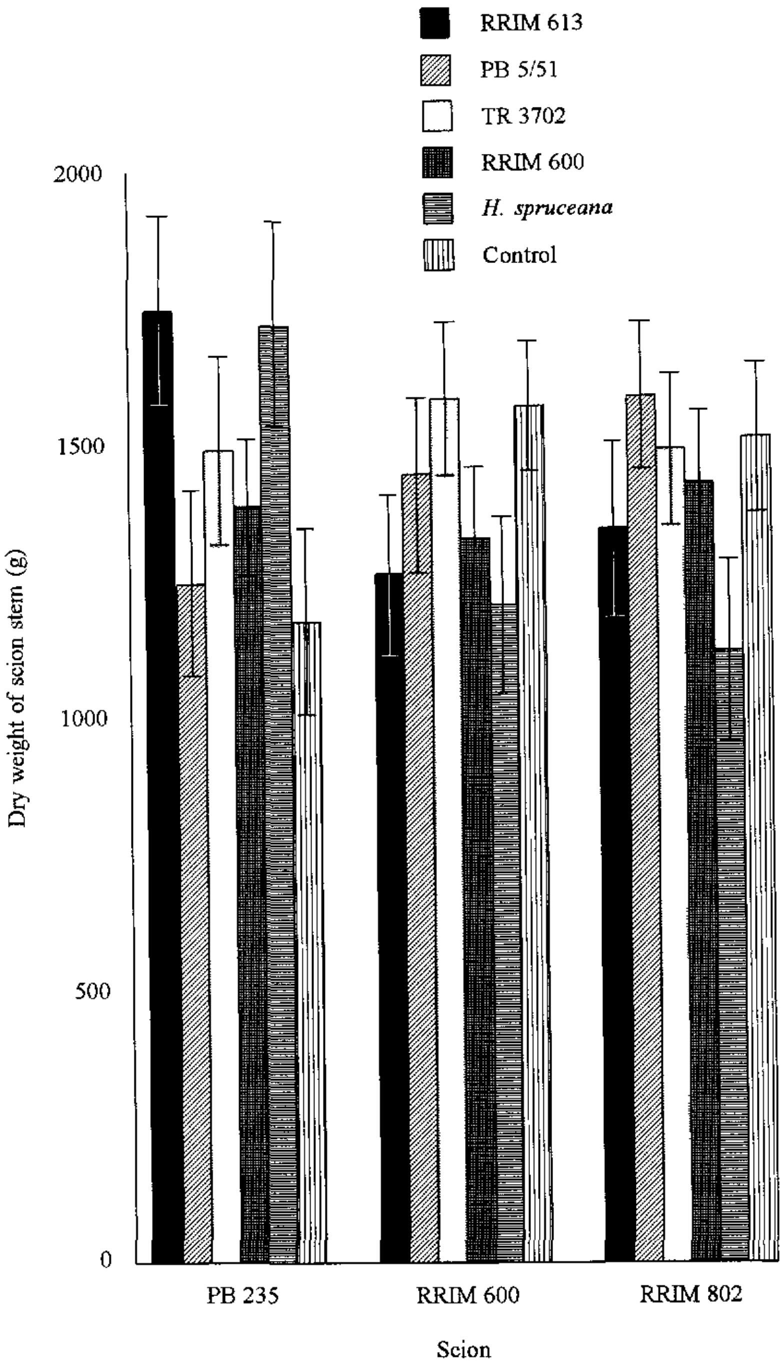

Figure 2. Effect of interstock clone on dry weight of scion at 1.5 years after planting. (Vertical lines represent SE associated with each combination mean.)

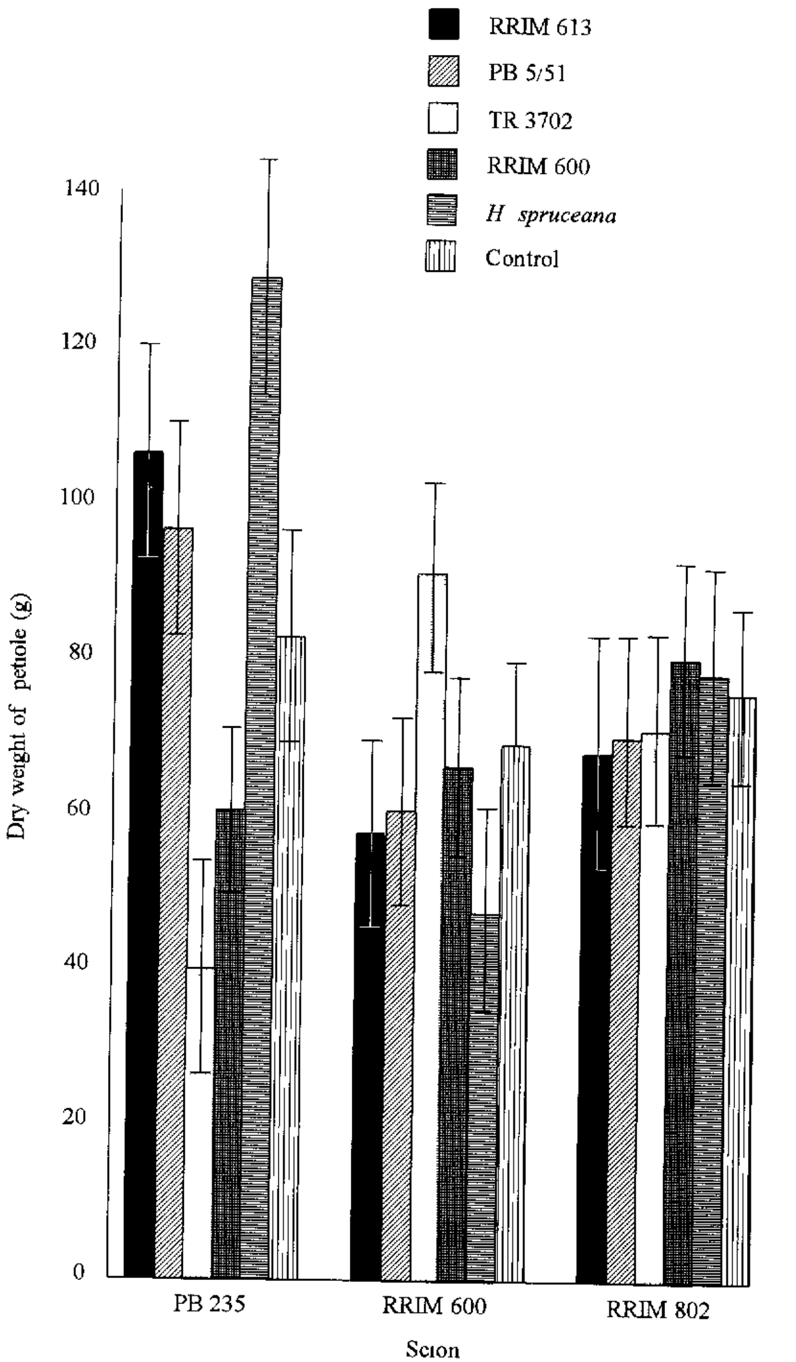

Figure 3 Effect of interstock clone on dry weight of petiole at 1 5 years after planting (Vertical lines represent SE associated with each combination mean)

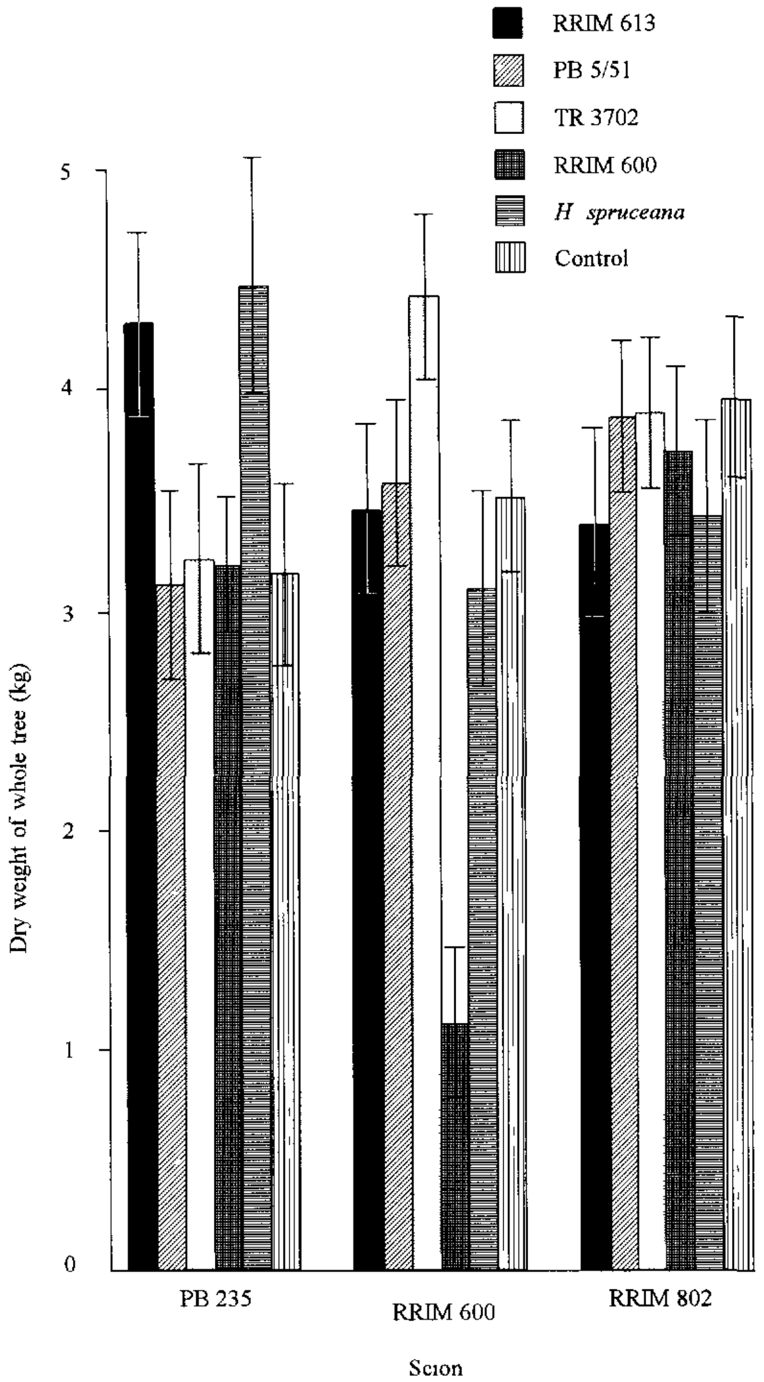

Figure 4 Effect of interstock clone on dry weight of whole tree at 1 5 years after planting (Vertical lines represent SE associated with each combination mean)

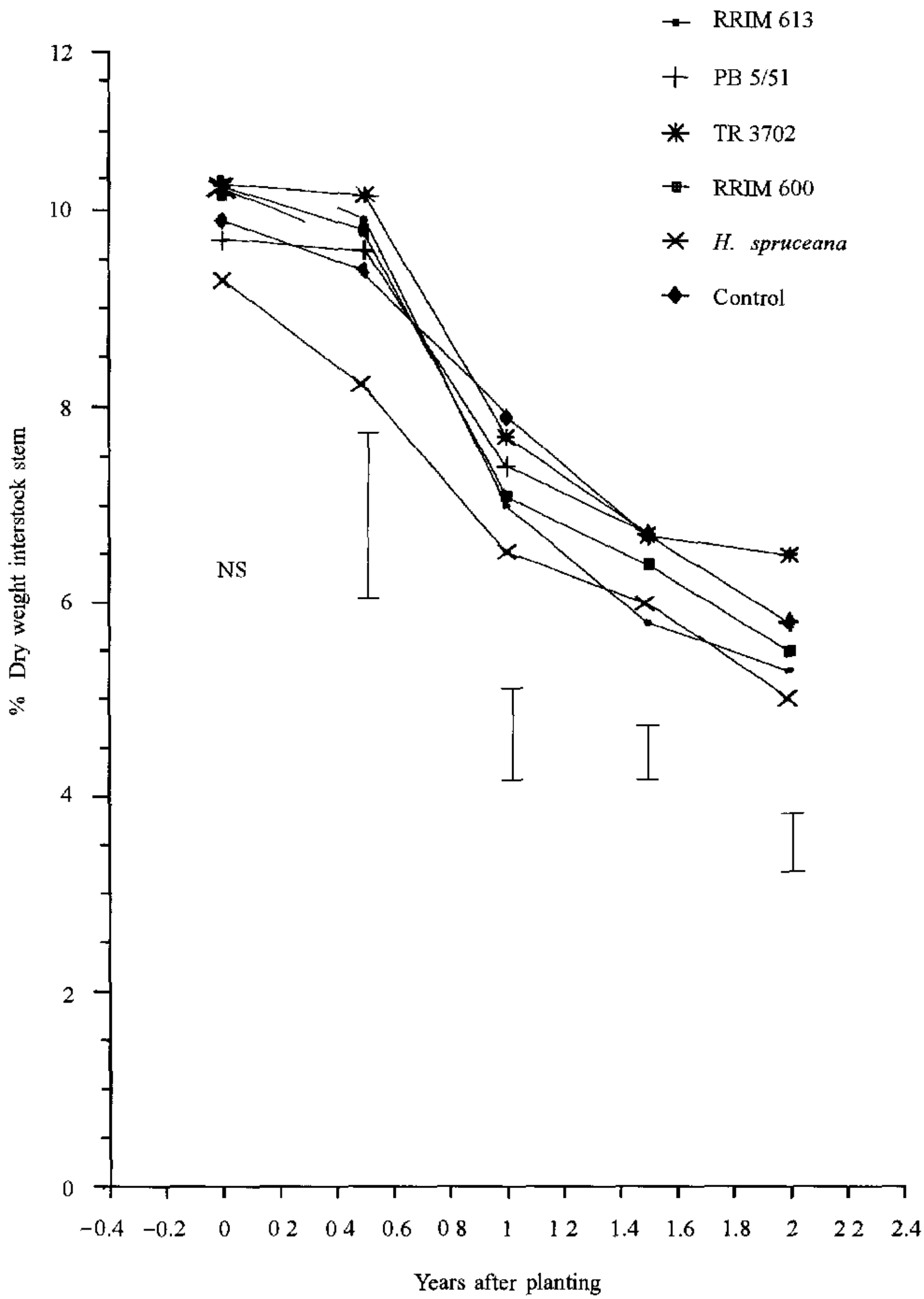

Figure 5 Effect of interstock clone on percentage dry weight of interstock stem. (Verticle bar represents least significant difference at P<0.05)

plants with RRIM 600 scion, TR 3702 interstock produced significantly higher LA than given by *H. spruceana* interstock.

At this interval, dry weights of RRIM 600 scion was not much affected by various interstocks (*Figure 2*). However, for combination with PB 235 scion, RRIM 613 and *H. spruceana* interstocks resulted in significantly higher dry weight of scion stem than given by control and PB 5/51 interstocks. For combination with RRIM 802 scion clone, the highest and lowest scion stem dry weight were given by PB 5/51 and *H. spruceana* interstocks, respectively. Petiole dry weight of RRIM 802 scion after 1.5 years of planting was not much affected by interstock clone (*Figure 3*). For PB 235 scion clone, *H. spruceana* and RRIM 613 interstocks produced substantially higher dry weight of petiole than those given by the control, RRIM 600 and TR 3702 interstocks. This pattern was reversed in RRIM 600 scion with TR 3702 and *H. spruceana* interstocks producing the highest and the lowest petiole dry weight, respectively.

The clonal differences in dry weight of interstock stem were also very highly significant at one and two years after planting (*Appendix 1* and *Table 2*) Additionally, there was a significant interaction between scion and interstock clone at these intervals. For all scion clones, differences in dry weight of interstock stem varied over the two harvesting intervals, although with the exception of the first-year harvest for RRIM 802 scion clone, there was a tendency for *H. spruceana* to have the lowest and TR 3702 interstock the highest stem dry weight.

At one year after planting, the influence of interstock on mean dry weight of

TABEL 2. DRY WEIGHT OF INTERSTOCK STEM AT ONE AND TOW YEARS AFTER PLANTING

Interstock clone	One year after planting Scion clone			Mean	Two years after planting Scion clone			Mean
	PB 235	RRIM 600	RRIM 802		PB 235	RRIM 600	RRIM 802	
RRIM 613	118.6	93.4	66.8	92.9	245.8	301.8	245.4	264.3
PB 5/51	90.3	79.2	93.9	87.8	270.7	317.5	399.6	329.2
TR 3702	136.7	109.2	64.2	103.3	424.4	295.8	422.5	380.9
RRIM 600	83.0	73.3	77.6	78.0	331.5	265.1	253.9	283.5
H. spruceana	61.0	68.4	53.2	60.9	252.3	191.8	285.8	243.3
Control	116.4	88.4	62.3	89.0	414.6	339.7	312.1	355.4
Mean	101.0	85.3	69.7	85.3	323.2	285.3	319.9	309.5
LSD (P<0.05) and level of probability:								
Scion |(S)		10.621	***			NS		
Interstock (I)		15.038	***			59.806	***	
Interaction (SxI)		26.53	**			105.182	*	

NS,*,**,***: F-test indicates non-significant or significant at p<0.05, 0.01 and 0.001, respectively roots depended on scion clone as indicated by significant interaction between scion and interstock clones (*Appendix 1*). The scion × interstock interaction was attributed to the fact that root dry weight of combinations with RRIM 600 scion clone was not much affected by interstock clones (*Table 3*). In comparison with the control, PB 235 scion in combination with RRIM 613 and TR 3702 interstocks increased root mass by 38% to 51% while a decrease by about 10% was recorded for combination with *H. spruceana* interstocks. For plants with RRIM 802 scion clone, PB 5/51 interstock increased root mass by 29% while those on *H. spruceana* interstock were reduced by about 17% compared with the control.

The effect of interstock clones on whole tree dry weight at one year after planting followed more or less the order expected from their effects on LA and dry weight of scion stem (*Table 1*). Trees on TR 3702 and RRIM 613 interstocks were similar in size as reflected by whole tree dry weight; these were 20% to 22% larger than the control. Trees on *H. spruceana* interstock were the smallest as their dry weights were only about 86% of the control.

At 1.5 years after planting, the interstock influence on whole tree dry weight differed among the scion clones because of the scion × interstock interaction. Whole tree dry weight of RRIM 802 clones was not influenced by interstock clone (*Figure 4*). For RRIM 600 scion clone, TR 3702 interstock clone resulted in the highest dry weight and *H. spruceana* interstock the lowest dry weight of whole tree. For combinations with PB 235 scion clone, *H. spruceana* and RRIM 613 interstocks produced comparable

TABLE 3 EFFECT OF INTERSTOCK ON DRY WEIGHT OF ROOTS AT ONE YEAR AFTER PLANTING

Interstock clone	Dry weight of roots (g)			
	Scion Clone			Means
	PB 235	RRIM 600	RRIM 802	
RRIM 613	712.1	480.8	363.6	518.8
TR 3702	651.1	523.5	360.6	511.7
RRIM 600	525.3	394.3	428.2	449 3
Control #	472.1	491.7	372.4	445.4
PB 5/51	454 7	378.3	480.5	437.8
H spruceana	424.3	456.3	310.6	397.1
Means	539.9	454 2	386.0	460.0

LSD (P<0.05) and level of probability.

Scion (s)	60.906	***
Interstock (I)	NS	
Interaction (S × I)	152.138	*

#: Control consists of plants in which the interstock and scion are of the same clone dry weight of whole tree which were significantly higher than those given by other interstocks.

Distribution of Dry Matter to Various Plant Parts

The ratios of plant parts to whole tree dry weights were calculated to estimate the relative partitioning of photosynthates to the plant parts. A close relationship has been reported in apples between the allocation of ^{14}C labelled assimilates of a particular plant part and its percentage dry weight[29]. In the present study, harvest date significantly influenced all percentage dry weight of plant parts tested while interstock clones only influenced percentage dry weight of scion stem, interstock stem and roots (*Appendix 2*). No significant interaction between harvest dates and interstock clones was detected for all plant parts indicating that the interstock effects were consistent across the harvest intervals. There was also no significant interaction between scion and interstock clones for these variables.

During the period of study and regardless of scion clones, *H. Spruceana* interstock stem consistently received the least allocation of dry matter followed by RRIM 613 interstock while the most allocation of dry matter went to TR 3702 followed by PB 5/51 and control interstock stems (*Figure 5*). The proportion of dry matter for scion stem was the lowest for *H. spruceana* interstock and highest for TR 3702 interstock following a pattern similar to its distribution in interstock stem (*Figure 6*). In contrast, *H. spruceana* and RRIM 600 interstocks gave significantly higher allocation of dry matter to roots than did TR 3702, RRIM 613 and PB 5/51 interstocks (*Figure 7*).

Growth Characteristics

Leaf area ratio. Harvest date significantly influenced LAR (*Appendix 2*). There was no significant difference in LAR due to the interstock clones when the results were analysed with harvest date as one of the variables. However, when the results were analysed separately for each harvest date, interstock influence on LAR was evident at one year after planting (*Table 1*). There was also no significant interaction between the effect of scion and interstock on LAR.

Specific leaf area. Scion clone and harvest date significantly influenced specific leaf area (SLA) ($P \leq 0.001$) (*Appendix 2* and *Figure 8*). However, SLA was not significantly influenced by interstock clones. There was also no significant interaction between the effects of interstock and harvesting date on SLA although such interaction was evident between the effects of scion clone and harvest date ($P<0.05$). The (scion × harvest date) interaction was because the scion difference in SLA was greater at time of planting when leaves were expanding than at other intervals. On the average, SLA of PB 235 and RRIM 802 scion clones was comparable and significantly higher than the value for RRIM 600 scion.

Mean Relative Growth Rate and Mean Net Assimilation Rate

Mean net assimilation rate (NAR) and mean relative growth rate (RGR) were derived from data of total LA and total above-ground dry matter accumulation, respectively. Mean NAR were significantly influenced by interstock clones and by the interaction effect between scion and

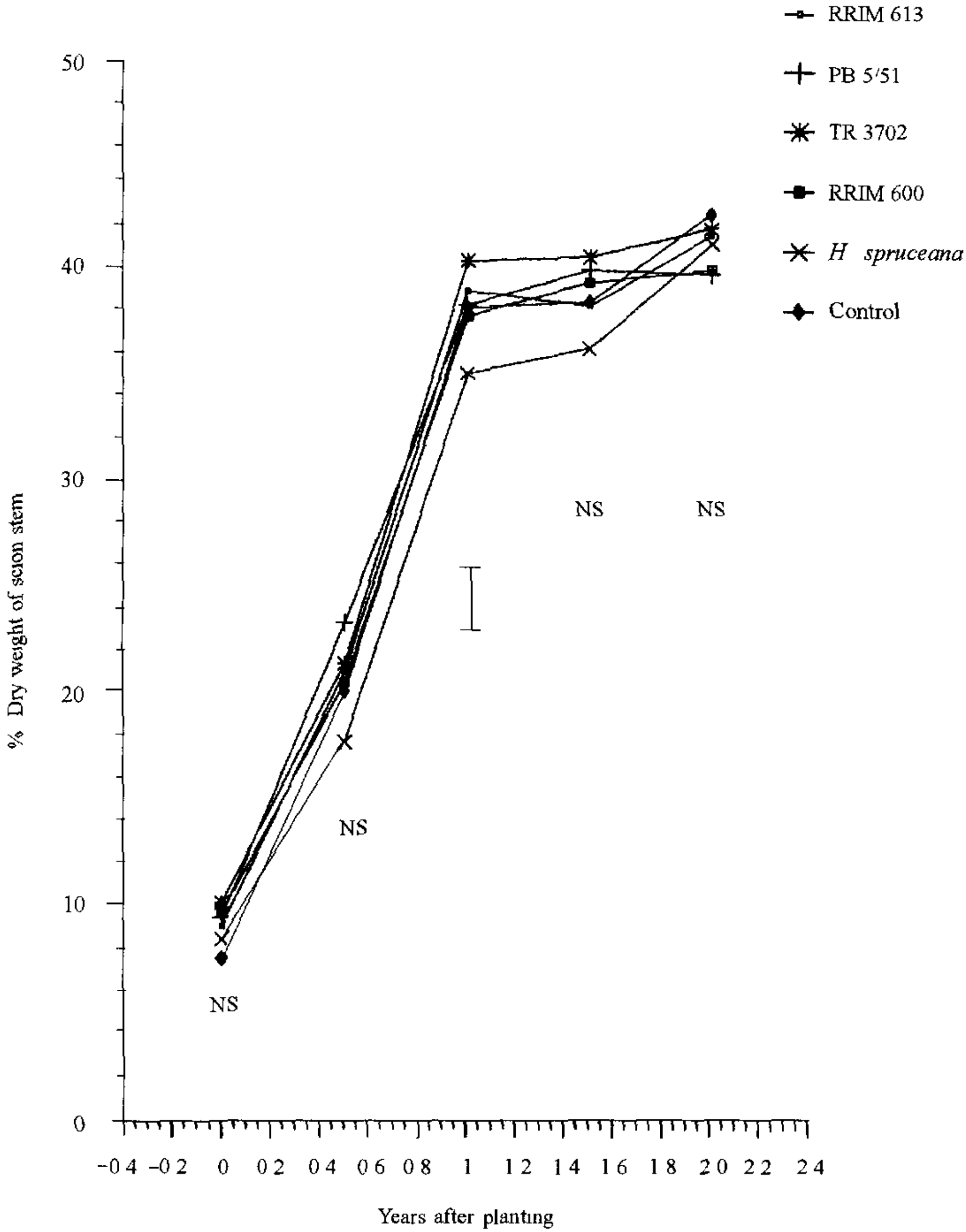

Figure 6 Effect of interstock clone on percentage of scion stem dry weight (Verticle bar represents least significant difference at P<0 05)

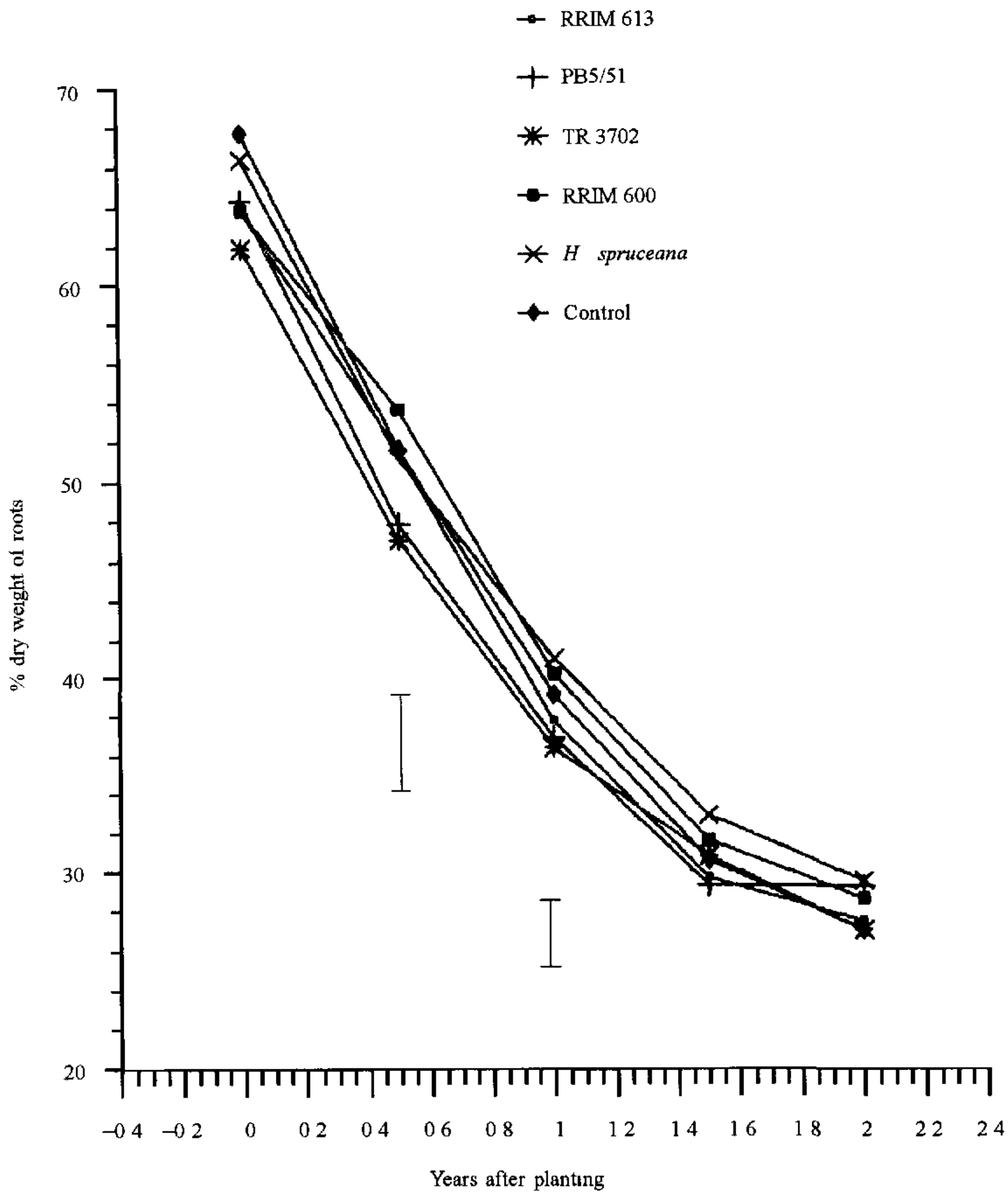

Figure 7 Effect of interstock on percentage dry weight of roots (Vertical bar represents least significant difference at P<0 05)

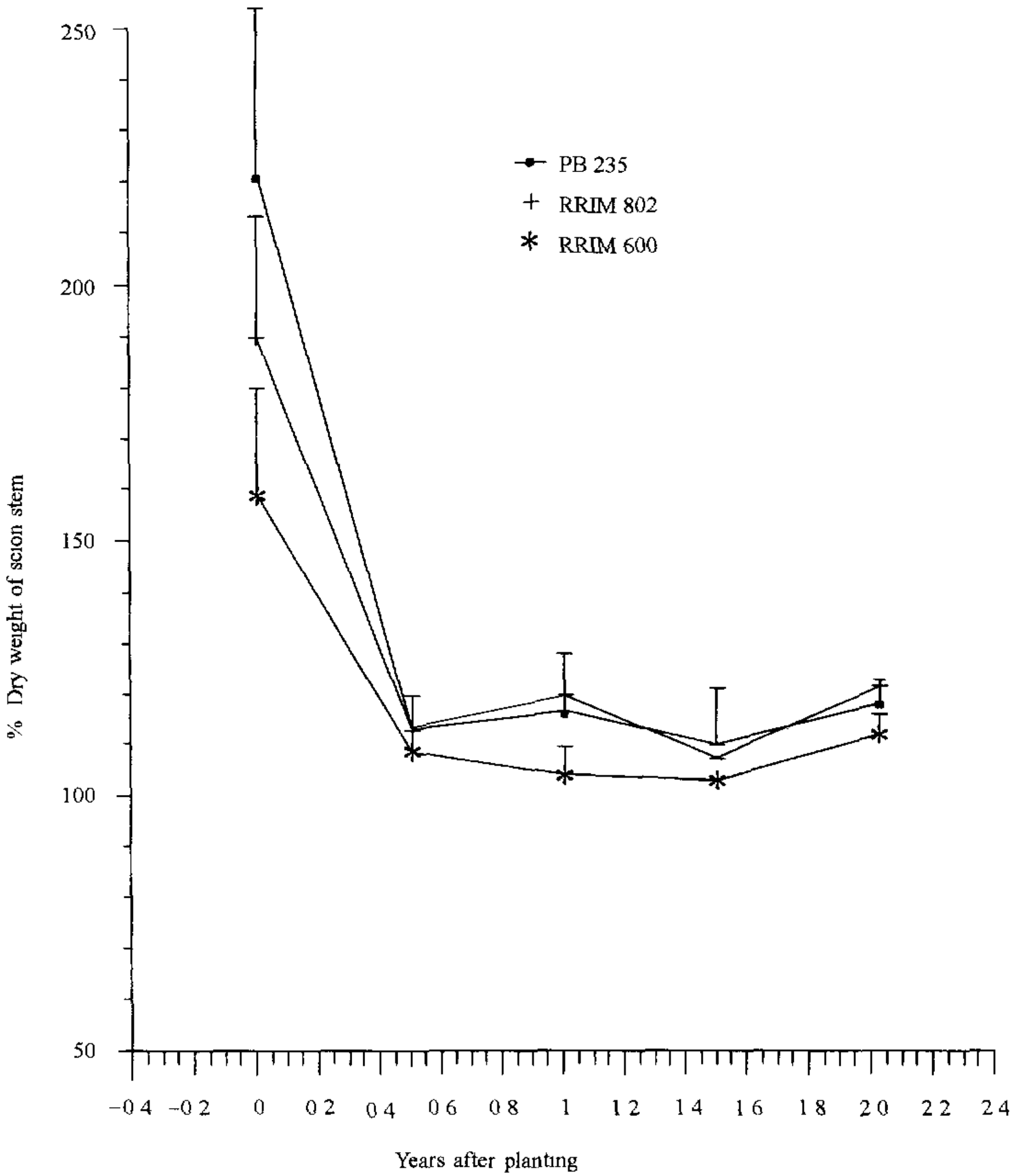

Figure 8 Specıfic leaf area of three scıon clones from 0 to 2 years after plantıng (Each poınt represents the mean of 6 ınterstocks +SD of the mean, some SDs are smaller than the symbols representıng each poınt)

interstock clones at all harvesting intervals (*Appendix 3*) Generally, for each scion clone, interstocks did not produce any consistent trend in mean NAR across the harvesting intervals (*Figure 9*). Mean NAR for all treatments generally increased two-fold between the 0–0.5 year and the 0.5–1.0 year intervals before declining slightly at the 1.0–1.5 year interval except for RRIM 802 scion clone which attained optimum values at the 1.0–1.5 year interval. At the final harvesting interval, mean NAR of all treatments declined two-to five-fold from the peak values with the exception of combinations with PB 235 scion grafted on TR 3702 interstock.

Reduced mean NAR observed from 1.5 year after planting reflects intense inter tree competition for light as the canopies began to overlap in the close planting stand[30, 31]. This would eventually cause a decrease in mean RGR values (*Figure 10*) since biomass is directly dependent on the daily radiation incident on the top of the canopy and on the fraction of incident radiation intercepted by the canopy[32]. Due to the presence of inter tree competition, only mean NAR and mean RGR results obtained during the first year of growth after planting merit discussion.

At 0–0.5 year interval, interstock clones did not improve mean NAR of RRIM 802 and PB 235 scion clones (*Figure 9*). However, PB 5/51 and TR 3702 interstocks resulted in higher mean NAR of RRIM 600 scion compared to the effect produced by control and *H. spruceana* interstocks. At 0.5–1 year interval, mean NAR of RRIM 600 scion clone on *H. spruceana* and control interstocks were significantly higher than those on PB 5/51 interstock. In contrast, RRIM 802 scion on PB 5/51 and RRIM 600 interstock clones and PB 235 scion in combination with RRIM 600, TR 3702 and RRIM 613 interstocks were significantly higher in mean NAR than their respective controls.

Results on mean NAR suggest that RRIM 600 scion had significantly higher photosynthetic capacity than had PB 235 and RRIM 802 scions, the values of which were not increased by the interstock clones. In contrast, photosynthetic capacity of RRIM 802 and PB 235 scion clones were further improved by RRIM 600, RRIM 613, TR 3702 and to a smaller extent by PB 5/51 interstock clones.

Mean RGR of the interstock plants more or less followed a similar trend as mean NAR across the harvesting intervals (*Figure 10*). Interstock clones significantly influenced mean RGR at all harvesting dates except at the final sampling interval. As with the mean NAR, there were also highly significant interaction between scion and interstock clones for mean RGR; thus results are presented for each scion clone. At 0–0.5 year interval, mean RGR of RRIM 802 and PB 235 scions were little improved by interstock clones compared to the control. However, PB 5/51 and TR 3702 interstocks resulted in higher mean RGR of RRIM 600 scion than produced by other interstocks. At 0.5–1 year interval, mean RGR of RRIM 600 scion was not much improved by various interstocks compared to the control. PB 5/51 interstock resulted in the highest and control interstock the lowest mean RGR of RRIM 802 scion. For combinations with PB 235 scion clone, RRIM 600, TR 3702 and

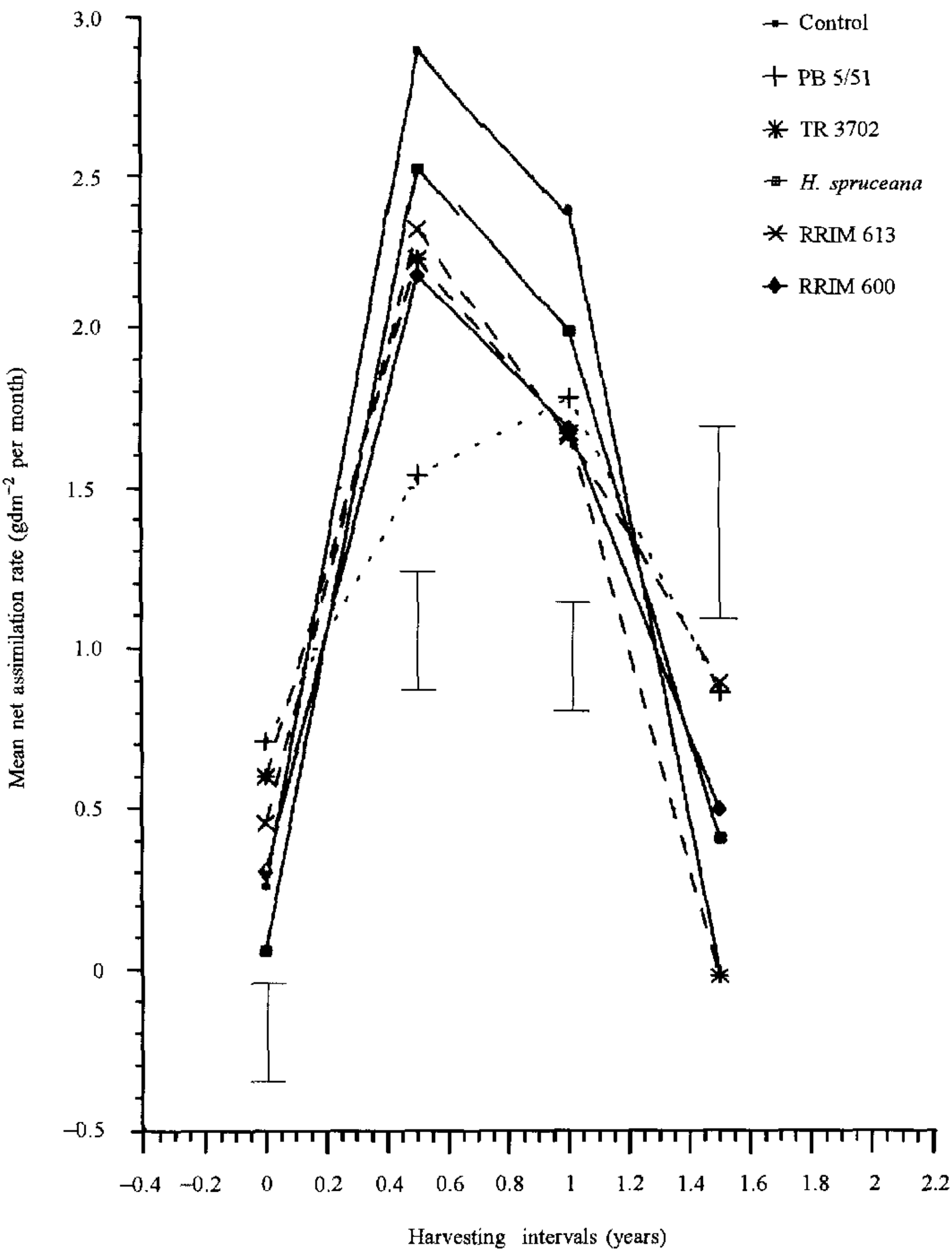

Figure 9a. Effect of interstock on net assimilation rate of RRIM 600 Scion. (Vertical bar represents least significant difference at $P<0.05$)

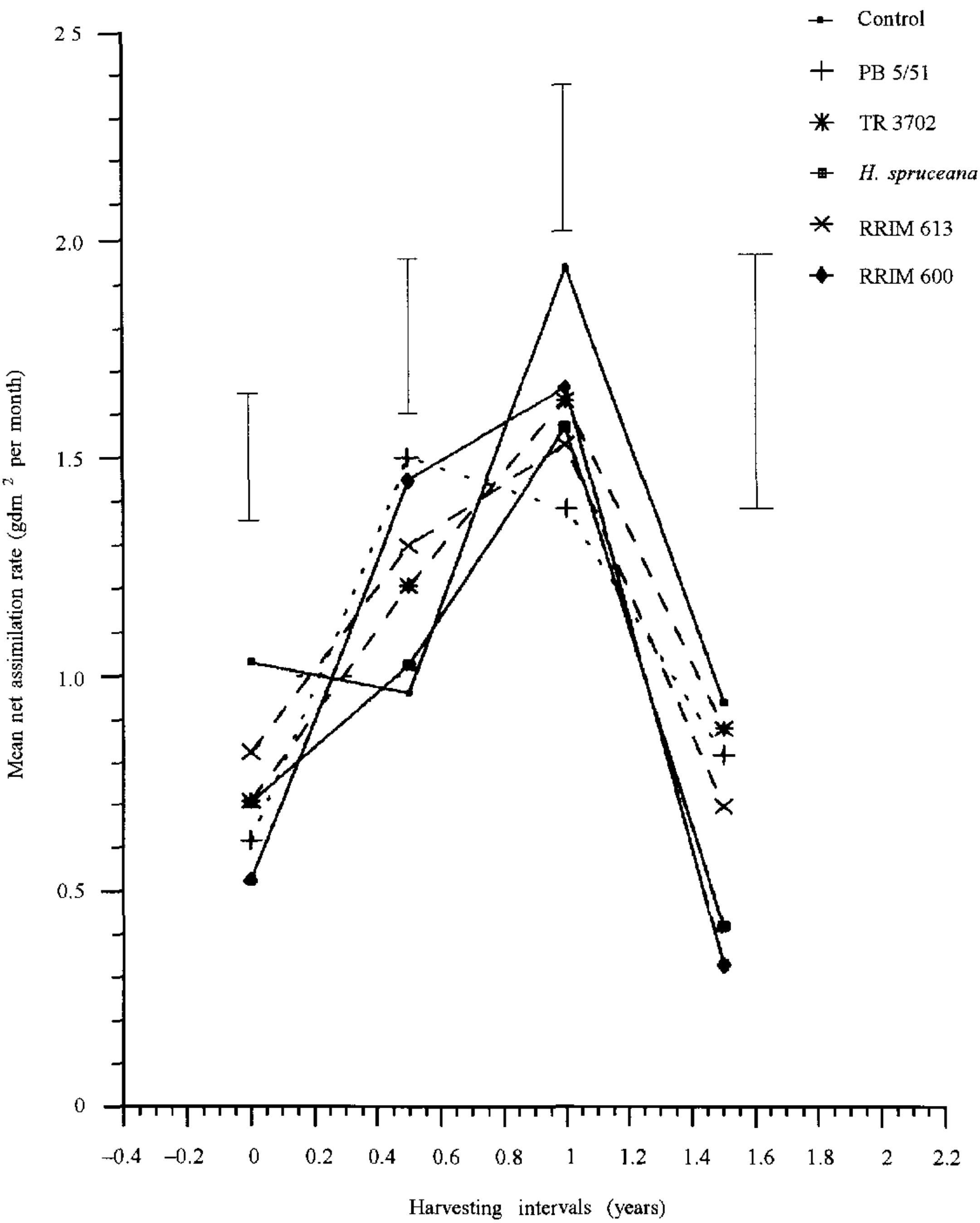

Figure 9b. Effect of interstock on net assimilation rate of RRIM 802 Scion. (Vertical bar represents least significant difference at P<0.05)

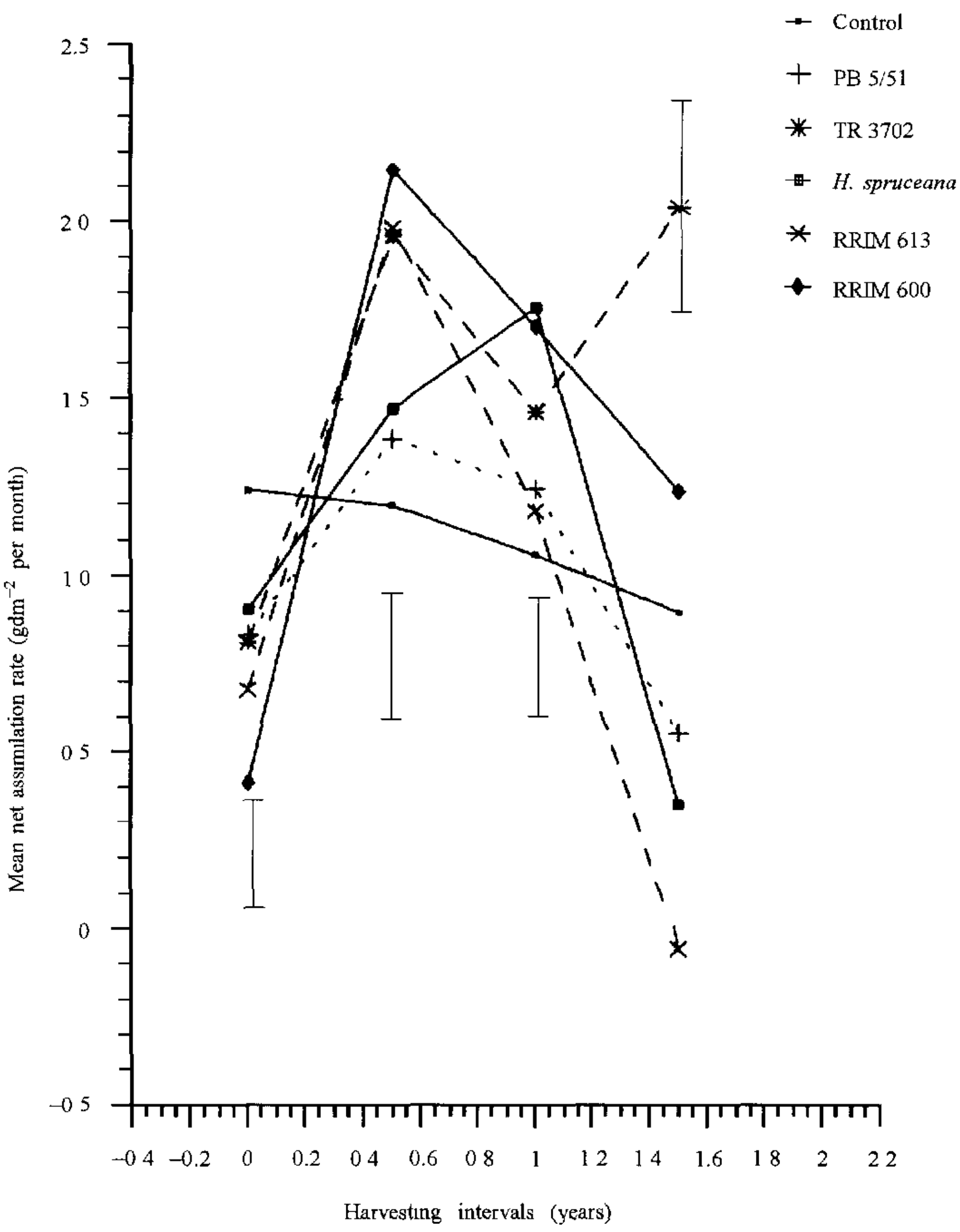

Figure 9c Effect of interstock on net assimilation rate of PB 235 scion.
(Vertical bar represents least significant difference at $P<0\ 05$)

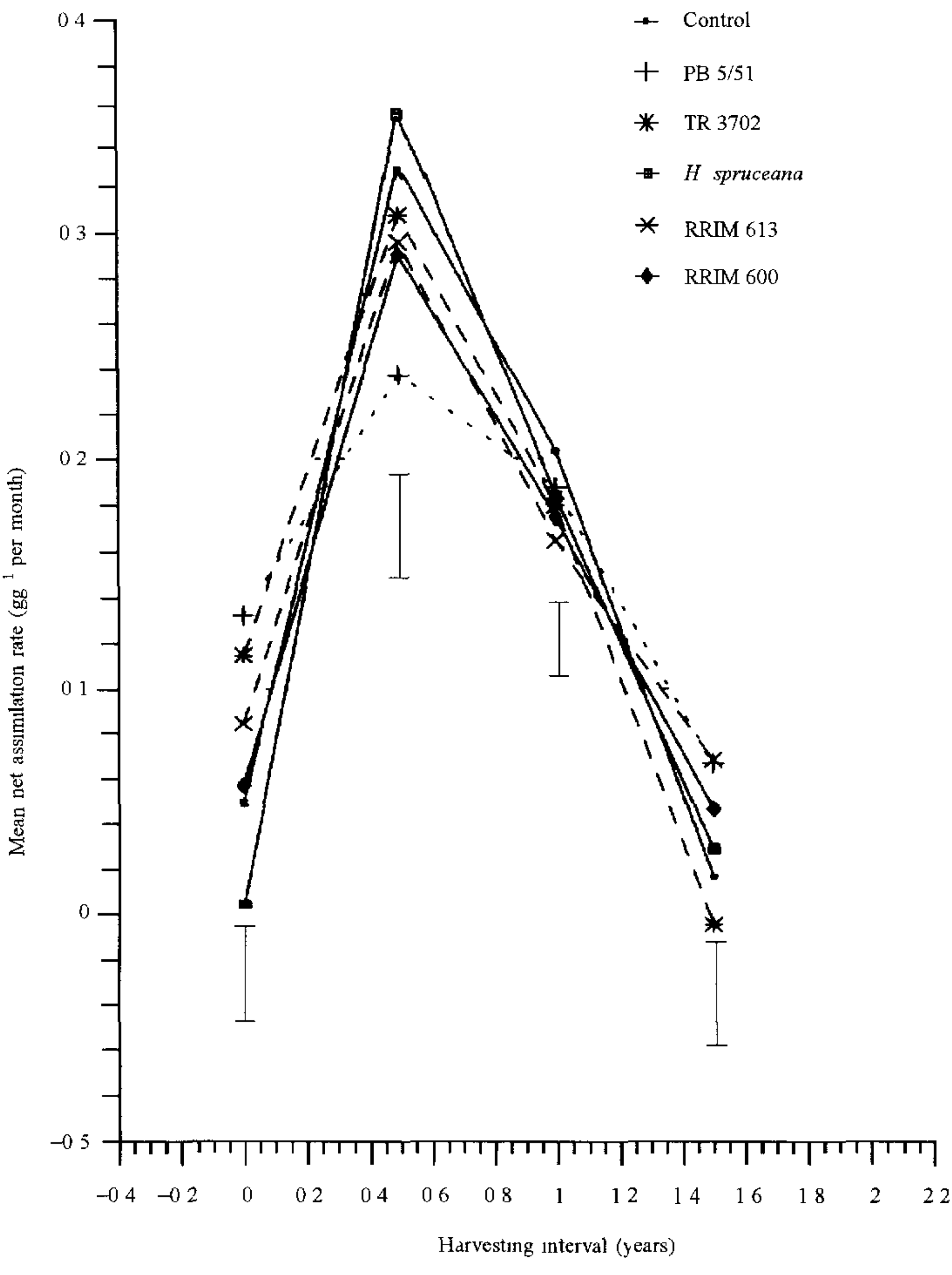

Figure10a Effect of interstock on mean relative growth rate of RRIM 600 scion (Vertical bar represents least significant difference at P<0 05)

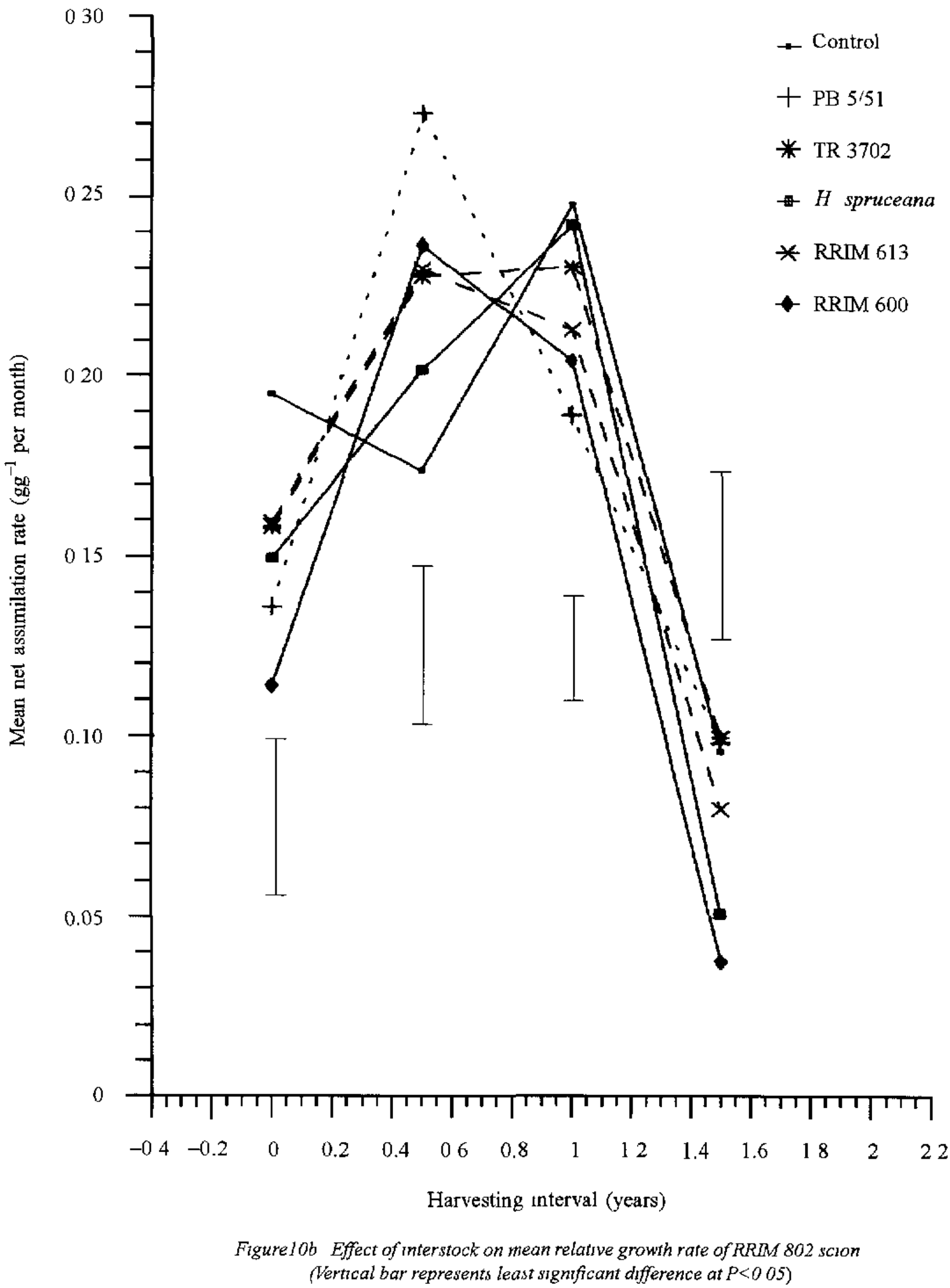

Figure10b Effect of interstock on mean relative growth rate of RRIM 802 scion (Vertical bar represents least significant difference at $P<0\ 05$)

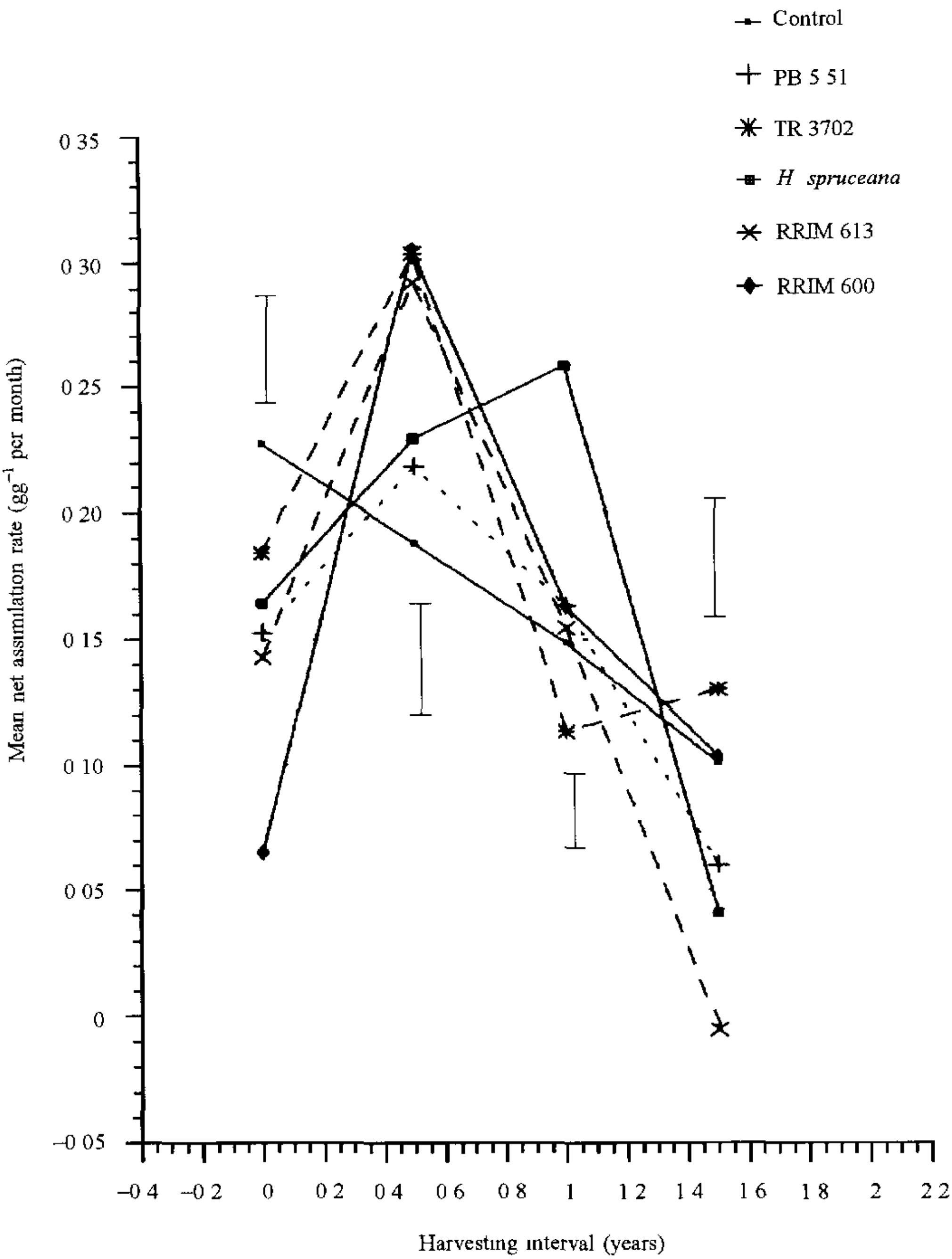

Figure10c Effect of interstock on mean relative growth rate of PB 235 scion (Vertical bar represents least significant difference at P<0 05)

RRIM 613 interstocks resulted in significantly higher mean RGR than those produced by *H. spruceana,* PB 5/51 and control interstocks.

DISCUSSION

The interstock influence on many parameters of growth was evident only at one year after planting (*Appendix 1*). Any tendency towards the expression of interstock influence in terms of growth during the first six months of growth after planting may have been masked by the great variability in growth as a result of non-uniform bud sprouting after grafting and to the different flushing rate of shoots after establishment. Similarly in apples, it was reported that the interstock influence on scion growth was evident only after the composite tree had reached a certain stage of maturity or stability in its growth which occurred after the first year of growth[33, 34].

In the present experiment, the absence of any interstock influence on leaf area and biomass of plant parts after the first year is probably because the interstock influence, being weaker than the scion influence (*Appendix 1*), was more prone to be confounded by the inter tree competition than the influence of scion. The inter tree competition is expected after the first year of growth due to the close planting distances in the ground nursery[35] which resulted in a sharp decline in mean NAR and mean RGR of the interstock plants in our study (*Figures 9* and *10*).

With the exception of data on mean RGR and mean NAR, and dry weights of interstock stem, roots and whole tree, the effects of interstock and scion on other aspects of growth were found to be additive, with mean squares for scion and interstock interaction being often statistically insignificant (*Appendix 1–3*). This is in concurrence with other reports on temperate fruit trees[12]. In the present investigation, most of these significant (S×I) interaction effects occured at 1.5 years after planting when the inter tree competition had set in; thus the interaction effect was obviously attributed to external factors and not due to the effects of treatment. On the basis of these explanations and unless otherwise stated, the following discussion on LA, LAR and dry matter production will refer to the observations made at one year after planting mainly on the main effect of interstock representing a mean response for the three scion clones. Similarly, results on growth analysis will refer to data taken during the first year of growth after planting. As this experiment was mainly concerned with interstock influence, the main effects of scion will only be mentioned whenever they are relevant to the influence of interstocks. This is despite the fact than in most of the growth parameters determined, scion influence was generally greater or equal to the influence of interstocks (*Appendix 1–3*).

The present experiment indicates that even though the interstock stem is only 20 cm in length and its development took only less than 10 percent of the total dry matter accumulation (*Figure 5*), yet it is an important sink as it influenced scion vigour, dry matter production, partitioning of assimilates to other vegetative plant parts and photosynthesis.

Data presented in *Table 2* show that in the composite tree, the differences in inherent vigour of the interstock clone, as reflected by the interstock stem dry weights, were very highly significant and were as strong as the influence of scion. This is to be expected since the interstock clones were selected based on their inherent vigour. Thus vigorous interstocks (TR 3702 and RRIM 613) generally had the largest stem dry weights while *H. spruceana* and RRIM 600 interstocks, with poor inherent vigour, had relatively lower stem dry weights.

The relationship of dry weights of interstock stem to LA and dry weights of other plant parts and whole tree were examined by correlation analysis to illustrate the importance of interstock vigour in determining scion and whole tree growth. Leaf area was used instead of laminae dry weight as preliminary studies had shown very highly significant and positive relationship between leaf area and laminae dry weight (r^2 = 0.933 or better). *Table 4* shows that there were significant and positive relationship between dry weights of interstock stem and scion stem for all three scion clones indicating that interstock vigour is important as it directly determines growth of scion. Absolute growth in terms of scion stem biomass and mean RGR calculated (*Table 1* and *Figure 10*) also showed this to be true. Thus vigorous interstock clones (TR 3702 and RRIM 613) produced better scion vigour than that of the less invigorating interstocks (RRIM 600 and *H. spruceana*) resulting in better overall growth of trees on the former interstocks. Similarly, Hewetson[33] working on apples had reported that the use of interstocks of variable vigour resulted in a range in tree size. However, for root dry weight and LA, significant relationship with interstock stem dry weights were only evident for RRIM 802

TABLE 4. THE RELATIONSHIP OF INTERSTOCK STEM DRY WEIGHT TO SOME GROWTH CHARACTERS AT ONE YEAR AFTER PLANTING

Scion clone	Growth character	Regression equation	Level of probability	r^2
PB 235	LA	0.8843 + 0.0104 x	*	0.661
	Scion stem DW	119.42 + 3 609 x	**	0.936
	Root DW	232.35 + 3 045 x	NS	0.531
	Whole tree DW	436.11 + 8 993 x	*	0.811
RRIM 802	LA	0.6774 + 0 0164 x	NS	0.581
	Scion stem DW	75 47 + 4 1021 x	*	0.755
	Root DW	87.36 + 4 305 x	***	0 974
	Whole tree DW	197 66 + 11.563 x	**	0 953
RRIM 600	LA	0.5159 + 0.0107 x	NS	0.473
	Scion stem DW	69.69 + 5.3404 x	**	0 922
	Root DW	213.94 + 2.815 x	NS	0.542
	Whole tree DW	−298.81 + 15 968 x	NS	0.241

n· 6
LA. Leaf area
DW: Dry weight
NS, *,**,***· F-test non-significant or significant at $p<0.05$, 0.01 or 0.001, respectively

and PB 235 scion clones, respectively (*Table 4*). This indicates that interstock clones affected growth of scion stem more than they did on LA and root growth. In contrast, studies in apple trees have shown that vigour potential rather than absolute growth of the interstock clone was important in influencing scion vigour[14]. It was also shown that dwarfing interstocks exerted greater influence on root growth than on shoot growth resulting in the interstock trees to be less firmly anchored than control trees. In the present experiment, significant relationship between interstock stem and whole tree dry weights was evident only for RRIM 802 and PB 235 scion clones but not for RRIM 600 scion (*Table 4*). This confirms the result of another experiment[36] in which there was a small significant interaction between scion and interstock clone with respect to scion girth; the interaction effect was attributed to the failure of RRIM 600 scion to be invigorated by various interstock clones.

The data presented here seem to indicate that the vigour produced by PB 5/51 interstock was comparable to that of RRIM 600 interstock (*Table 1*), while PB 5/51 as a rootstock was reported to exert more superior influence on scion growth than that of RRIM 600 rootstock[1]. This seems to suggest that in *Hevea*, an interstock may not have similar effect as a rootstock; this concurs with the view that the influence of a clonal material on *Hevea* performance when present either as a scion or rootstock and probably interstock too, is not necessarily the same and may differ markedly[1]. This phenomenon has also been reported for other temperate crops such as apple, citrus, quince, cherry and plum[37,38].

Several explanations can be advanced to account for the invigorating effect of interstock clones on scion growth in the present experiment. Improved scion growth seems to involve a greater allocation of photosynthetic assimilates to scion stem (*Figure 6*). Associated with this greater allocation has been a parallel increase in the photosynthetic rate of scions as indicated by mean NAR calculated (*Figure 9*) and in parameters associated with photosynthesis such as LA and stomatal size[36].

This is consistent with the concept of interstock stem being part of a source sink system of the composite tree whereby the demand for assimilates by active sinks (interstock and scion stems) would invariably lead to an increase in photosynthetic rate of scion leaves[39]. Maggs[40] also reported increased NAR of cropping apple trees where fruits are active sink compared to either deblossomed or defruited trees. However, photosynthesis and LA may not be the limiting factors for growth of these composite plants. This is based on the observation that LAR values which reflect the relative size of the assimilatory apparatus, did not seem to be related to vigour induced in the scion (*Table 1*). Moreover, the consistently lower SLA values of RRIM 600 scion relative to the other two scion clones over the study period (*Figure 8*) may also reflect thicker leaves and/or carbohydrate accumulation in leaves of RRIM 600 clones[41]. Thicker leaves usually have higher photosynthetic capacity than thinner leaves since the resistance to CO_2 diffusion to the chloroplast are substantially reduced due to an increase in thickness of palisade parenchyma or to greater pore space in the mesophyll layer[42-44]. Since mean NAR in RRIM 600 scion was 34% to 83% greater than those of

PB 235 or RRIM 802 scion clones (*Figure 9*), this would lend support to this explanation.

It is apparent in the present experiment that vigorous interstocks (TR 3702 and RRIM 613 clones) are active sinks which improved scion vigour by increasing the sink strength of scion stem (*Figure 6*), a process probably involving plant hormones such as gibberelic acid[45]. The active sinks would then have a greater capacity to remove assimilates from the phloem, thereby giving it a competing edge over other sinks especially the roots for dry matter[39]. In other plants, it has been shown that treatments which increased gibberellin activity in a particular organ has led to a concomitant increase in its sink strength for available assimilates[46,47]. Similarly in apples, vigorous interstock also resulted in greater accumulation of dry matter in branches and stem than in roots[48]. Evidently, in the present experiment, root growth was the most seriously affected by the competition from vigorous scion stem for assimilates than growth of leaves and interstock stem. However, in the presence of weakly growing competing sinks such as *H. spruceana* and RRIM 600 interstocks, sink strength of scion stem was not increased; more assimilates would then be available for extra growth in the roots. This is consistent with the evidence found in other perennial trees that the root system becomes a major sink for photosynthates when active growth of shoot is reduced[29,49].

CONCLUSION

The use of interstock in the propagation of *Hevea* may be costly because of the additional budding process involved. However, where cost is not a limiting factor, interstock may be a practical approach to improve tree growth with no suitable monoclonal seedling rootstocks. Before interstock can be recommended as a planting material, more tests need to be carried out for the most suitable interstock and scion combinations because of the presence of scion × interstock interaction. Future research might also be directed to study the relative influence of interstock and rootstock on scion performance to ascertain whether the slight increase in scion vigour would justify the expense of making the three-part-tree. This paper shows that two outstanding interstocks were RRIM 613 and TR 3702 clones which increase the sink capacity of scion and provide an efficient dry matter partitioning towards scion growth during the early stage of plant growth. Early vigour of high yielding scion clone will ensure a higher potential for latex and timber yields during the later part of the economic life of the tree. This is particularly pertinent in the current context where there is a high demand for rubberwood by the timber industry.

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APPENDIX 1

ANALYSIS OF VARIANCE FOR LEAF AREA AND DRY WEIGHTS OF VARIOUS PLANT PARTS MEASURED OVER THE EXPERIMENTAL PERIOD

Source of variation	df	Mean squares						
			Dry weight					
		Leaf area	Laminae	Petiole	Scion stem	Interstock stem	Root	Whole tree
<u>At time of planting</u>								
Scion clones (S)	2	NS 0.053	NS 55.188	NS 3 892	NS 63.099	NS 13.229	NS 2000.844	NS 2704 045
Interstock clone (I)	4	NS 0.026	NS 49.167	NS 3.472	NS 49.738	NS 59.626	NS 2106.071	NS 4398.548
Interaction (S×I)	8	NS 0.048	NS 66 148	NS 4 308	NS 35 145	NS 12 407	NS 490.480	NS 1465 133
Error	94	0 038	73.683	4 058	53 416	25.577	971.287	2527 758
<u>0.5 year after planting</u>								
Scion clone (S)	2	NS 0 109	NS 582.658	** 107.673	NS 482.079	NS 247.319	NS 9577 420	** 75229.916
Interstock clone (I)	5	NS 0.032	NS 203.481	NS 17 108	NS 1424.198	NS 205.326	NS 1667 657	NS 18281.447
Interaction (S×I)	10	NS 0.035	NS 236.114	NS 28.095	NS 277 895	NS 67.031	NS 2389.259	NS 16768.326
Error	105	0.035	273 391	19.165	998.239	104.884	2486.443	10736.480
<u>1.0 year after planting</u>								
Scion clone (S)	2	*** 2.721	* 11968.629	*** 4012.484	*** 286756.042	*** 9671 352	*** 234397.223	*** 1180173 677
Interstock Clone (I)	5	* 0 923	* 9379.771	** 446.861	* 99431.142	*** 4150 722	NS 43009.159	** 450801 423
Interaction (S×I)	10	NS 0.440	NS 39166.411	NS 205.653	NS 22991.175	*** 1853.636	* 45081.402	NS 200625.257
Error	104	0.339	2426.293	120.329	26253 808	582.414	19153.451	118481 294

APPENDIX 1 (CONTD)
ANALYSIS OF VARIANCE FOR LEAF AREA AND DRY WEIGHTS OF VARIOUS PLANT PARTS MEASURED OVER THE EXPERIMENTAL PERIOD

Source of variation	df	Leaf area	Mean squares					
			Dry weight					
			Laminae	Petiole	Scion stem	Interstock stem	Root	Whole tree
1.5 year after planting								
Scion clone (S)	2	12.11 *	84627.88 *	4506.41 *	26696.65 NS	12563.95 *	58528 91 NS	152509.98 NS
Interstock Clone (I)	5	2 51 NS	21219.19 NS	843.60 NS	73525 23 NS	6902.65 NS	88691.41 NS	451491.00 NS
Interaction (SxI)	10	11.87 ***	94215.69 ***	4028 16 ***	338036.17 *	5321.22 NS	120522.54 NS	2331459.75 NS
Error	113	2.64	19304.61	1091.49	157720.16	3674 34	95108.89	1081512.45
2 years after planting								
Scion clone (S)	2	132.97 ***	733736.40 ***	16730.21 **	2578037.70 *	17958.25 NS	1342917.28 ***	16240624.09 *
Interstock clone (I)	5	3 18 NS	225499.47 NS	555 34 NS	1474617.58 NS	58961.28 ***	252667.39 NS	6468391 20 *
Interstock (SxI)	10	10.44 NS	75938 41 NS	5005.43 NS	1254718.49 NS	20289.82 *	246685.02 NS	6843455.20 NS
Error	108	8 45	57813.07	2524 70	693536.30	9580.68	179335 62	3699823.77

NS *, **, ***: F-test indicates non-significant or significant at P<0.05, 0.01 and 0.001, respectively

APPENDIX 2
HARVEST DATE SCION AND INTERSTOCK EFFECTS ON LEAF AREA RATIO (LAR), SPECIFIC LEAF AREA (SLA) AND PERCENTAGE DRY WEIGHTS OF VARIOUS PLANT PARTS

Source of variation	df	Mean squares						
				Percentage dry weight				
		LAR	SLA	Laminae	Petiole	Scion stem	Interstock stem	root
Scion clone (S)	2	150.610 ***	498 611 ***	46.192 ***	3 953 ***	20.198 *	3.220 **	49.967 **
Interstock clone (I)	5	6.643 NS	15.519 NS	3.233 NS	0 091 NS	16.478 *	2.982 ***	27 174 **
Harvest date (H)	4	720 400 ***	430.101 ***	173.228 ***	12 646 ***	3563.485 ***	65 339 ***	4109.497 ***
Interaction (S × I)	10	7.700 NS	19.002 NS	1.575 NS	0 223 NS	4.124 NS	0 472 NS	4.666 NS
Interaction (S × H)	8	12.175 *	55 891 *	4.203 NS	0.278 NS	24.725 ***	0.763 NS	12.897 NS
Interaction (I × H)	20	5.902 NS	15.197	1 630 NS	0.147 NS	3.991 NS	0.375 NS	5.337 NS
Error	40	4.780	19 775	2.250	0.178	4.933	0 563	6.828

NS, *, **, ***: *F-test indicates non-significant or significant at P<0.05, 0.01 and 0.001, respectively*

APPENDIX 3
ANALYSIS OF VARIANCE FOR MEAN NET ASSIMILATION RATE AND MEAN RELATIVE GROWTH RATE OVER THE EXPERIMENTAL PERIOD

Source of variation	df	Mean Squares x 10^2			
		Harvest dates (years after planting)			
		0–0 5 year	0 5–1 0 year	1 0–1 5 year	1 5–2 0 year
Mean net assimilation rate					
Scion (S)	2	185 91***	1021 32***	198 04***	151 11***
Interstock (I)	5	42 15***	48 83***	40 33***	75 36*
Interaction (S × I)	10	30 48***	102 30***	41 53***	207 31***
Error	101	7 01	10 49	9 16	29 38
Mean relative growth rate					
Scion (S)	2	8 26***	5 97***	3 05***	1 83***
Interstock (I)	5	1 72***	0 77***	0 82***	0 42 NS
Interaction (S × I)	10	0 98***	1 29***	0 55***	1 06***
Error	101	0 14	0 16	0 07	0 17

NS, *, **, *** F- test indicates non-significant or significant at P<0 05, 0 01 and 0 001, respectively