FULL-SPIRAL TAPPING

1. PRELIMINARY REVIEW OF THE PROGRESS OF EXPERIMENTAL WORK WITH NOTES ON PRACTICAL ASPECTS OF FULL-SPIRAL TAPPING

BY

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Summary

1. Experiments are described in which full-spiral fourth-daily tapping (S/1,d/4,100%) has been compared with alternate-daily tapping on half-spiral cuts (S/2,d/2,100%) on both budded and seedling rubber trees. The trees in the majority of experiments were young and of comparatively small size.

2. *Yield has been increased in all experiments* by full-spiral tapping. Clones vary widely both with regard to the rapidity with which they have responded to the system and the ultimate increase in yield.

3. The proportion of low-grade rubber has been increased and the dry-rubber-content of the latex from young trees has been somewhat depressed.

4. *Tapping cost has been greatly reduced*, the average saving being over 35 per cent while, for some clones, the economy has been considerably greater.

5. *Growth*, estimated by girth measurements, *has been reduced*, the retardation of growth being greatest when the full-spiral system was applied to young buddings of small size. The growth of seedlings of comparatively large size has not been greatly affected and it appears that older well-grown buddings are affected to a smaller extent.

6. The experiments have not been in progress for sufficiently long to give conclusive information on the relation between full-spiral tapping and bark renewal.

7. The incidence of brown bast has not been significantly affected.

8. A discussion of these results leads to the following conclusions:—

(a) For *young and small trees* (under 24 inches girth) S/1,d/4,100% tapping is *not considered suitable* as a permanent tapping system on account of the retardation of growth. For several years, however, yield may be increased and tapping cost reduced.

(b) Less evidence has been obtained on the response of *older and larger* trees but it appears that the retardation of growth is less serious and it is considered that full-spiral tapping shows considerable promise as a permanent tapping system for mature areas of highyielding rubber trees. Further evidence must however be awaited before a definite conclusion is reached.

9. Practical aspects of full-spiral tapping are discussed in Appendix I. Emphasis is laid on the importance of strict control of tapping. Other safeguards are also described. If this advice is carefully followed it is considered that the system can be employed without undue risk and with the prospect of considerable profit in suitable areas.

Introduction

The quest for a tapping system which will give the maximum yield with the greatest economy of labour has recently led increasing numbers of planters to consider the introduction of full-circumference tapping. It has, therefore, been felt desirable to publish a first review of the experimental work now in progress on this subject.

By way of introduction reference should be made to the origin of full-spiral tapping. In 1919 Sharples and Lambourne (1924) employed full-spiral cuts tapped daily, alternate daily and third daily in studies on brown bast disease. Subsequently they used three-quarters and seven-eighths spiral cuts. No attempt was made to develop a permanent tapping system, but the results are of interest since the lengthened cuts caused marked increases in yield while the incidence of brown bast was much less severe than had been expected. A few years later full-spiral cuts, tapped daily, were employed successfully as a method of slaughter-tapping in Sumatra.

Interest in full-spiral tapping was revived in 1929 when "slump" conditions emphasised the importance of "economic" tapping systems. Experiments were undertaken by the Technical Department of the Socfin Company in Malaya to determine whether full-circumference cuts could be employed in *permanent* tapping systems. These pioneer investigations covering the years 1931 to 1933 have been described by Gain (1935). Fourth-daily tapping on full-circumference cuts gave most promising results. This system, originally known as "the Socfin system," was later adopted widely in Indo-China as well as by a few other companies in Malaya. Little was however known with regard to the ultimate effects of the system on the development of trees and the investigations described in this paper were consequently undertaken by the Rubber Research Institute. The earlier experiences of the

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Socfin Company have provided a background of great value in this work.

In this paper continuous fourth-daily tapping (S/1,d/4,100%) is compared with the usual half-spiral alternate daily system (S/2,d/2,100%) with respect especially to yield, tapping cost and growth. The possibilities of other full-spiral systems are also examined. The investigations are still at a comparatively early stage but it is already evident that if adequate care is exercised full-spiral tapping may be applied most profitably and without danger *to certain types of tree.* On the other hand *the incautious introduction of the system may lead to most undesirable results.* It must be emphasised however that much wider experience of full-spiral tapping is necessary before making a final decision on its value as a *permanent* system. Further reports will be published in due course but it is considered that sufficient evidence is now available to justify the introduction of full-spiral tapping as a commercial system on suitable areas, provided that the various safeguards outlined in the appendix to this paper are observed. Experimental work is now sufficiently advanced for it to be possible to issue an early warning should later results indicate that any modification of these recommendations is necessary.

Experimental Results

The annual results of experiments on seedling and budded rubber trees in which full-spiral and half-spiral tapping have been compared are summarised in Table I. Fuller data are given in Appendix II. The yield and tapping cost per pound of dry rubber for S/1,d/4,100% tapping are expressed as percentages of the corresponding figures for the control system (S/2,d/2,100%). These percentage comparisons, termed *relative yield* and *relative tapping cost,* are the most convenient basis for assessing the effects of modification of the tapping system. Growth has been assessed by girth measurement. The annual girth increment and the *relative increments* are both shown in Appendix II. Relative girth increment has been selected as the most convenient basis for assessing the effects of tapping treatments on growth. The standard errors for yield and girth are shown in Appendix II. Fuller statistical data will be published in due course when detailed papers on the individual experiments are prepared. It will be seen that the errors in yield are greater for experiments Nos. 42 and 43 than for the other investigations.

General details of the type and history of the trees in the different areas are given in Appendix II and for the purpose of a

TABLE I

The Effect of Full-Spiral Fourth-Daily Tapping (S/1,d/4,100%) on Yield, Tapping Cost and Growth: Summary of Experimental Results

		Seedling Rubber	B.D. 5	B.D. 10	Tj. 1	Tj. 16	S.R. 9	Ct. 88	Avros 50	Avros 71	Avros 256	Mixed P.B. Clones
Experiment No.		47	6, 34, 46	42	7, 8	42	42	42	42	42	42	33
	Year											
RELATIVE YIELD OF TOTAL CROP	1	117	138	120	140	97	97	182	132	117	68	113
	2	135	144*	136	124*	120	107	174	139	144	114	106
	3	154		141		107	111	145	119	139	149	
	4	143										
	5	145										
RELATIVE TAPPING COST	1	66	54	63	54	77	77	41	57	64	110	63
	2	55	51*	55	61*	63	70	43	54	52	66	67
	3	50		53		70	68	52	63	54	50	
	4	52										
	5	52										
RELATIVE GIRTH INCREMENT	1	92	60	57	55	69	85	47	78	76	87	80
	2		57*									100
	3			57		68	105	62	90	86	71	
	4	97										
	5											

Results for six months only.

preliminary survey little need be added to the description of the experiments which has already appeared in the Annual Reports of this Institute (1935-1939). The investigations fall into two classes: "*full-task*" *experiments* indicated by the letter "T" in Appendix II and "*single-tree plot*" *experiments* indicated by the letter "S." The method of the "full-task" experiments is in all essential points similar to commercial practice. Each plot is a normal tapping task, the full-spiral tasks being 70% of the size of those in half-spiral tapping. Records for yield of No. 1 rubber, scrap and d.r.c. are obtained in the manner described by Guest (1940).

In the "single-tree plot" experiments much smaller numbers of trees are used and separate records are kept for each tree, there being sufficient replications to give valid results. The total crop from each tree is coagulated in the tapping cup. After drying, the "cup lumps" so obtained are weighed in monthly batches and in calculating the total yield these weights are adjusted for the moisture which remains occluded in the lumps after drying. With this method of recording neither separate estimates of No. 1 and low-grade rubber, nor determinations of d.r.c. are made.

Yield

It will be seen from Table I that S/1,d/4,100% tapping has usually led to much higher yields than the usual S/2,d/2,100% system in both seedling and budded rubber. Only one experiment (No. 47) has so far been carried out on seedling rubber. Initially full-spiral tapping led to a comparatively small increase in yield but for the third, fourth and fifth years of the experiment the yield has been increased by over 40 per cent. To reduce the effect of varying tapping height on these results half the control trees were originally opened at 20 inches and half at 40 inches. Full-spiral cuts were opened at 30 inches only.

Budded rubber trees of a number of clones have been studied and it will be seen from Table I that they have varied greatly in the degree to which they have responded to full-spiral tapping. Yield has in every case been increased but in some clones the effect has not occurred until the second year of full-spiral tapping. The extent to which clones respond is not directly dependent on the level of yield in half-spiral tapping. In Table II the responses of seven clones in one experiment (No. 42) are compared. Clone Tj. 16, the highest yielding clone, gives the second lowest relative yield in full-spiral tapping, though the degree of response of the other clones is roughly in the same order as their yields under the control tapping system.

TABLE II

Response of Different Clones to S/1,d/4,100% Tapping in Experiment 42

Mean Yield of control system (S/2,d/2,100%) in pounds per tree per annum and Mean Relative Yield of S/1,d/4,100% system for three years

Clone	Tj. 16	Ct. 88	Av. 71	B.D. 10	Av. 50	S.R. 9	Av. 256
Mean Yield per tree per annum of Control system (S/2,d/2,100%) (pounds per tree)	9.50	9.46	9 12	9.05	8.30	6 29	4.80
Mean Relative Yield of S/1.d/4,100% system	108	167	133	132	130	105	110

In some clones the yield response of full-spiral tapping appears rapidly while in others it develops slowly. In Experiment 42 (see Table I) clone Ct. 88 responded most rapidly, the maximum effect of S/1,d/4,100% tapping occurring in the first year when the yield was nearly doubled. On the other hand the yield of clone Avros 256 was very low for the first six months of full-spiral tapping, the yield *per tapping* being very little greater than in the control treatment; and the relative yield for the first year was only 68. In the third year however relative yield was increased by approximately 50 per cent. The other clones in this experiment are intermediate between Ct. 88 and Av. 256 in this respect.

It is of interest in this connection to examine the responses of these clones to daily alternate-monthly tapping on half-circumference cuts, (S/2,d/1,m/2,100%). The daily yield curves for this tapping system in the same experiment (see Annual Report R.R.I.M., 1939) show that after the cuts were reopened at the beginning of the month the yield of Ct. 88 rose and declined rapidly, the daily yield falling below the mean yield for the month on the 24th day. Avros 256 on the other hand was slow to commence yielding and the yield curve was still rising at the end of the month. The curves for other clones fall between these extremes. Thus it appears that clones which commence yielding rapidly on half-spiral cuts after rest also respond rapidly to full-spiral tapping.

The above results do not make it possible to predict the degree to which clones not previously tapped on full-spiral cuts will

ultimately respond to this system, but it appears likely that the yield of all clones will be increased to a greater or less extent. Clones which are slow to commence yielding on new cuts may however be expected to show a temporary decline in yield when alternate-daily tapping is replaced by fourth-daily tapping.

Ratio of No. 1 to Low-Grade Rubber

In Table III the yield of low-grade rubber is expressed as a percentage of the total crop for the "full-task" experiments. The increase in low-grade rubber is due mainly to late dripping after the normal time of collection and it will be seen that this effect is more marked for Clone Tj.1 and mixed P.B. Clones than for B.D.5. In view of this high proportion of low-grade rubber, the economic benefit of full-spiral tapping is somewhat less than the relative total yield figures indicate. In commercial practice it is however, often possible to reduce the amount of scrap rubber by a second collection of latex at a small additional cost.

TABLE III

Effect of S/1,d/4,100% Tapping on Percentage of Low-Grade Rubber

First year of experiments

Experiment No.	Clone	Low grade rubber as percentage of total crop			Significant difference (P = 0.05)
		S/2,d/2,100% (Control)	S/1,d/4,100%	Difference	
6	B.D. 5	10.0	14.7	4.7	0.46
7	Tj. 1	13.1	20.2	7.1	1.01
33	Mixed * P.B. Clones	11.1	19.1	8.0	—

* see note (6) Appendix II

Dry-Rubber-Content

Dry-rubber-content has been depressed by full-spiral tapping in those experiments for which records have been taken. Table IV shows that the effect has been significantly less in Clone B.D.5. than in the other clones. Later results, not yet complete, indicate that this effect may decrease as the trees increase in age.

TABLE IV

Effect of S/1,d/4,100% Tapping on Dry-Rubber-Content

First year of experiments

Experiment No.	Clone	d. r. c.		Significant difference (P = 0.05)
		S/2,d/2,100% (Control)	S/1,d/4,100%	
6	B.D. 5 -	38.7	37.1	0.79
7	Tj. 1 -	38.8	35.2	0.69
33	Mixed * P.B. Clones -	33.9	31.4	

* See note (6) Appendix II

TASK SIZE AND LABOUR CHARGES

Tapping cost is determined by yield per tapper which in turn depends on task size and yield per tree. It is therefore convenient to discuss these factors together.

On account of the longer time required to tap trees in full-spiral than in half-spiral tapping the task size must be reduced. The size of a full-spiral task relative to a half-spiral task is here termed the "task-size ratio." On estates where full-spiral tapping has been adopted in commercial practice it has been usual to adopt a task-size ratio of 70 per cent. Thus if the yield per tree were the same for trees tapped on the two systems the economy in tapping cost would be over 28 per cent.* As, in practice, yield per tree is usually increased by S/1,d/4,100% tapping the economy in tapping cost may be considerably greater. This is clearly shown by the results for the three "full-task" experiments (No. 6, 7 & 33) in Appendix II.

In the "single-tree plot" experiments the tapper taps both full- and half-spiral cuts in the same task. The ratio of time he spends on trees on full- and half-spiral tapping should therefore

* If full-spiral tasks are 70 per cent of the size of half-spiral tasks, the former being tapped fourth-daily and the latter alternate-daily, it follows that the number of *different* trees a tapper can tap over a period of days in the two systems is in the ratio

$$\frac{\text{half-spiral}}{\text{full-spiral}} = \frac{2 \times 100}{4 \times 70} = 0.714$$

If the yield of rubber per tree is the same for both treatments, the tapping cost per pound for full-spiral tapping would therefore be 71.4 per cent of the cost for half spiral-tapping. The saving is therefore 28.6 per cent.

give an indication of the best task-size ratio. The time spent tapping each tree in several of the experiments was therefore measured with a stopwatch and the task-size ratios were calculated. In different experiments the ratio varied between 61 and 72 per cent. It thus appears that tasks on full-spiral tapping should be approximately two thirds (66.7%) of the size of tasks with half-spiral cuts. With this task-size ratio, the economy in tapping cost will be 25 per cent when the yield per tree per annum is the same for both systems. This figure has been used to calculate tapping cost for the "single-tree plot" experiments in Table I.

The tappers employed in these experiments had previously tapped half-spiral cuts and were tapping both full- and half-spiral cuts during the course of the experiments. It is not unreasonable to assume that, when tappers are constantly tapping on one system only, they will attain a higher level of efficiency. Thus the task-size ratio of 70 per cent may prove satisfactory when large areas are placed on this system on a commercial basis.

It is evident that the number of tappers required will be reduced by at least a quarter when full-spiral tapping is introduced. Thus all overhead expenditure on labour and equipment for tapping will be lowered. This economy is additional to the saving in tapping cost per pound of rubber. It has sometimes been claimed that expenditure on supervision can also be decreased in proportion to the reduction in the size of the tapping force but such economy is not advocated. The dangers attendant on bad tapping may be greater in full-spiral than in half-spiral tapping and every effort should be made to improve the tapping standard by *careful control.*

Growth

The figures for relative girth increment in Table I show that growth has been markedly reduced by full-circumference tapping. An inspection of the results indicates that the extent of this retardation of growth is related both to relative yield and tree size (see Appendix II). The greater the increase in yield caused by full-spiral tapping, the greater has been the retardation of growth (see Table I), the effect tending to be most marked in the smallest and youngest trees which should normally be growing most rapidly. This is shown by Table V in which the relative girth increments for large, medium, and small trees in five experiments have been calculated separately. The majority of the trees in these experiments were small, only 17 per cent. exceeding 24 inches in girth at tapping height when the experiments were laid down, but the data indicate that the relative girth increment of the larger trees is greater than that of the smaller trees in these experiments.

TABLE V

The Relation between Tree Girth and the Relative Girth Increment of Trees Tapped S/1,d/4,100%

Experiment No.	Clone	Relative Girth Increment		
		Under 20 inches girth	20—24 inches girth	Over 24 inches girth
6	B.D. 5	67	59	75
7	Tj. 1	45	67	70
8	"	—*	42	44
34	B.D. 5	27	33	—*
46	"	52	62	67
	Mean	**48**	**53**	**64**
Percentage of trees in class		27%	56%	17%

* Insufficient trees to allow valid estimates to be made.

Further evidence that the growth of older and larger trees is less affected is provided by Experiment No. 47 in which seedling trees of comparatively large size have been tapped for five years. During the last two years growth in the S/1,d/4,100% system has been approximately the same as in the control though yield has been increased by over 40 per cent. A tendency for the retardation of growth to diminish with increasing age is also shown by several of the clones in Experiment 42 (Table I). Clone Avros 256 is an exception, but the greater retardation of growth in the third year than in first two years for this clone is very probably due to the fact that there was no great increase of yield in the full-spiral treatment until the third year. In Experiment 34 although the relative girth increment has increased only slightly in the first half of the second year the actual increment in inches (see Appendix II) is nearly equal to the increment for the entire first year. In the second year of Experiment 33 growth has equalled that of the control.

Although further results must be awaited before a final conclusion on the effect of full-spiral tapping on the growth of large trees is reached, the above evidence suggests that in estate practice the retardation of growth should be less severe than has been found in the present investigation, since the average tree size

at the commencement of the experiments was lower than is usual in areas coming into commercial tapping.

The measurements of girth increment here discussed were made *above* the tapping panel. In a few experiments on young trees girth measurements have also been made three inches from the union. The retardation of growth in the first year was greater below than above the tapping cut. This suggests that the "ringing" effect of the full-spiral cut retards translocation down the trunk to a significant degree in young trees.

Bark Consumption

In the experiments here described bark consumption has been on the average 5 to 10 per cent. greater per tapping than in the S/2,d/2,100% system. It has been pointed out above (p. 9) that the tappers had been previously employed on trees on alternate-daily tapping and it is therefore not improbable that with increasing experience they could maintain a lower rate of bark consumption. It is reported from certain estates on which strict control of tapping is enforced that the standard of tapping has been raised so much that the bark consumption per tapping for trees in the S/1,d/4,100% system is now approximately equal to that previously maintained in S/2,d/2,100% tapping.

In particularly dry areas the greater drying-out of the bark during the interval of four days between tappings may make it impossible for this rate of bark consumption to be achieved but it would appear that no anxiety need be entertained concerning bark consumption provided that adequate control of tapping is maintained.

Bark Renewal

Some of the most serious doubts which have been entertained with regard to full-spiral tapping are on the score of bark renewal at the base of the tapping panel when new cuts are opened above. As the first tapping panel has not yet been completed in the experiments here described no evidence on this point has so far been obtained. Experiments on the subject have been undertaken recently both at the Experiment Station of this Institute and on estates. It may be noted however that satisfactory bark renewal has been reported from some estates where full-spiral cuts have been opened above renewing bark. Practical aspects of this question are referred to in Appendix I.

Brown Bast

An increase in the incidence of brown bast has been reported as a consequence of full-spiral tapping, but in the experiments

here reviewed no significant increase in brown bast has yet been recorded for trees tapped on the S/1,d/4,100% system.

Alternative Full-Spiral Systems

In the majority of these investigations S/1,d/4,100% was the only full-circumference system employed but in three experiments other full-spiral systems were included and the results are given in Table VI.

TABLE VI

Comparison of Full-Spiral Systems of Different Intensities

First year of experiments

Clone	B.D. 5			B.D. 5			Tj. 1		
Experiment No.	46			34			8		
	Rel. Yld.	Rel. Tapg. Cost	Rel. Girth Incr.	Rel. Yld.	Rel. Tapg. Cost	Rel. Girth Incr.	Rel. Yld.	Rel. Tapg. Cost	Rel. Girth Incr.
Tapping System									
S/2,d/2,100% (Control) -	100	100	100	100	100	100	100	100	100
S/1,d/4,100% -	135	56	63	146	51	55	149	50	43
S/1,d/4,10m/12,83% (wintering rest) -	125	50	68	127	49	55	126	50	45
S/1,d/3,133% -	155	65	66	157	64	55	173	58	50
S/1,d/3,3m/4,100% -	119	63	73	121	62	72	134	56	61
Significant Difference (5% point) -	11.6		15.8	10.2		13.7	14.0		9.8

Note: Girth was measured *above* the tapping cut

A rest for two months during the wintering period (S/1,d/4, 10m/12,83% tapping) has resulted in a comparatively small decrease in yield, a reduction in tapping cost for clone B.D. 5 and no significant alteration in growth rate. Further results must however be awaited before the full effect of wintering rest can be determined.

The only other full-spiral system with periodic rest for which results are at present available is third-daily tapping for three

months in four (S/1,d/3,3m/4,100%). This system has resulted in reduced yield and increased growth as compared with S/1,d/4,100%. It seems probable that longer periods of rest and tapping, such as S/1,d/3,6m/8,100% would have been more satisfactory; a number of periodic systems at various intensities are being investigated.

Full-spiral tapping third-daily without rest (S/1,d/3,133%) has resulted in greater yield than the normal fourth daily system (S/1,d/4,100%) but tapping cost was increased. Girth increment was not significantly different in the two systems. Third daily tapping on full-spiral cuts is however too intense for practical application.

Discussion

The merits of a tapping system must be judged by three criteria, namely its effect on yield, its effect on the development of the tree and its effect on tapping cost. The ideal tapping system would be one that combines maximum yield and minimum tapping cost with best growth and bark development. Such perfection is however unattainable since increased present yield is obtained to a greater or less extent at the expense of growth, especially when trees are young. It has been shown (Ann. Rep. R.R.I.M., 1938) that the growth of trees may be greatly retarded if yield is raised by alteration in the tapping methods and conversely that the growth and yield of trees may be improved when a too heavy tapping system is replaced by a lighter one (Ann. Rep. R.R.I.M., 1940). In other words a negative correlation exists between yield and growth.

The reason for this situation is not far to seek. The carbohydrates photosynthesised in the leaves of the tree are the substratum from which both new plant tissue and latex are formed, so that the greater the amount of latex* produced, the less material is available for growth processes. Increased latex production without decreased growth can be obtained only if the production of carbohydrates in the leaves is also increased. Hence it is clearly of particular importance that trees which it is proposed to tap intensively should be maintained in the best possible condition by sound cultivation, by manuring if necessary and by the efficient control of pests which would place an additional strain on the

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* In addition to rubber, latex contains a complex of non-caoutchouc substances about which little is known. Without knowledge of the physiological role of these various constituents, of latex it is not possible to estimate the drain on the constitution of the tree occasioned by their removal in tapping. No exact relationship between material removed in tapping and potential growth is suggested nor can the effect of wound response as opposed to yield in tapping be assessed.

resources of the tree. For any tree there is an optimum level of latex production above which increased yield is not in the long run economic. Many areas, of seedling rubber trees especially, are already tapped at or above this level, a fact proved by the benefit which often results from the resting of trees (Annual Report R.R.I.M., 1940). A consideration of this fact suggests that, by the modification of tapping methods alone no large *permanent* increase in crop can be obtained except under the most favourable conditions although *temporary* large increases can readily be procured.

Tapping cost, the third criterion of the efficiency of a tapping system, is determined by yield per tapper and not by total yield. Consequently tapping methods which reduce the number of tappers without affecting yield are of considerable economic value. In the light of the considerations outlined above it would appear that the greatest opportunity for the improvement of tapping methods is by reducing tapping cost rather than by attempting to increase the yield of areas which are already tapped at the optimum intensity.

Effect of Full-spiral fourth-daily tapping on yield and tapping cost. The investigations described in this paper have shown full-spiral fourth-daily tapping (S/1,d/4,100%) to be definitely superior to the usual S/2,d/2,100% system when judged by its effect on both *present* yield and tapping cost. It appears however that the effect of full-spiral tapping on the future yield and development of trees may in *some cases* be so deleterious as to outweigh the present benefits of the system. The remainder of this paper will be devoted to the discussion of this question.

Effect of Full-spiral fourth-daily tapping on Growth. The marked retardation of growth resulting from S/1,d/4,100% tapping has already been noted. It is the most serious consequence of the system which has so far been observed. The effect is to a large extent directly related to high latex production, the extent of retardation varying inversely with increased yield for trees of the same age and condition. This is shown in Table I. In Experiment 42 where the responses of several clones to S/1,d/4,100% tapping were compared, Ct. 88 which gave the greatest increase in yield for the first year showed also the most marked retardation of growth. On the other hand in the second year of Experiment 33, the increase in yield was small and growth was equal to that in the control. In other words the decline in growth rate should be regarded as primarily a result of high yield rather than as a direct consequence of full-spiral tapping. There is however evidence that the retardation of the growth of *young*

buddings is not traceable solely to increased yield. In Experiments 8, 34 and 46 a large number of tapping systems at different intensities, employing both full- and half-spiral cuts, have been used (Annual Report R.R.I.M., 1939, and 1940). A detailed analysis of the data on girth and yield thus obtained would be out of place in this discussion but it may be noted that the retardation of growth of trees in continuous full-spiral tapping is in excess of the retardation which would be expected in equally high-yielding treatments employing half-spiral cuts. On the other hand the periodic resting of trees in full-spiral tapping benefits growth to a greater extent than would be expected on the basis of reduction in yield. This effect has been found only in very young, rapidly growing trees. Further results must be awaited before the effect of S/1,d/4,100% tapping on the growth of older trees can be definitely assessed but there is evidence (Table V) that as trees increase in age and the normal growth rate declines, the retardation in growth becomes less serious. In this connection it is of interest that in certain commercial areas it has been reported that growth is seriously retarded only in trees under 24 inches in girth.

There is another aspect of the effect of tapping on the rate of growth of a tree which merits consideration. *All* tapping systems retard growth as compared with untapped trees and the effect of full-spiral tapping in this direction differs in degree rather than in kind from the effect of alternate-daily tapping on half-circumference cuts (C/2,d/2,100%). The generally accepted systems of tapping half-circumference cuts at 100 or 67% intensity have been adopted in the light of experience because they can be safely employed with minor modifications, over a long period of production, possibly for a tapping life of 30 years. It is possible that future improvements in the quality of planting material and in methods of replanting may make it advisable on economic grounds to revise our views on the profitable life of a rubber plantation and to plan for more intensive exploitation of existing plantings at the same time making provision for replacement with improved high-yielding material. If this view is accepted it follows that a tapping system of greater intensity than those normally employed at the present time may be used since, despite its greater effect in retarding the rate of growth, it may not prove too severe for the reduced period of production required. Reduced rate of growth may also be offset by maintaining a somewhat higher density of trees per acre.

Effect of Full-spiral fourth-daily tapping on bark renewal. Less definite observations can at present be advanced on the effect of full-spiral tapping on bark renewal. It has been suggested, not

unnaturally, that a tapping system which retards growth is likely to have a bad effect on bark renewal especially below the tapping cut. Experimental evidence on this question should soon be available. It is however encouraging that reports of satisfactory bark renewal have been received from estates where full-spiral cuts have been opened on a second panel, though until the cuts reach the base of the panel this question cannot be settled. It is reasonable to expect that trees which show satisfactory growth are least likely to suffer from bad bark renewal.

In view of the above facts it is clear that caution and careful measurements of growth and bark renewal are particularly necessary when full-spiral cuts are opened above renewing bark but it may be possible to offset poor bark renewal by resting the trees or by shortening the tapping cuts temporarily.

Alternative full-spiral systems. Trees which cannot stand up to S/2,d/2,100% tapping must be expected to respond even less favourably to the more severe S/1,d/4,100% system.* Hence trees which show a high incidence of brown bast or other undesirable features in normal S/2,d/2,100% tapping are unlikely to respond favourably to continuous tapping on the S/1,d/4,100% system. This is not however, the only possible full-spiral system. Full-spiral systems with periodic rests have as great, or even greater, possibilities than the widely used "A.B.C." and other periodic systems with half-spiral cuts, and it is necessary that more experimental work should be done with such systems as S/1,d/4, 6m/9,67% or S/1,d/4,8m/10,80%. Already some evidence is available to show the benefit of periodic rest (see discussion of growth above) and this inference is supported by the experience of planters who have employed full-spiral methods at reduced intensity.

Physiological effects of full-spiral tapping. Finally reference may be made to the physiological effects of the so-called "ringing" (i.e. interference with translocation) of a tree by full-spiral tapping. In the absence of detailed physiological observations it is not possible to estimate the extent to which the translocation of plant food down the tree is restricted by full-spiral cuts. That the reduction of translocation is significant for young trees is however suggested by a number of observations. The girth increment of young trees is reduced by full-spiral tapping to a greater extent than is to be expected as a result of increased yield and it has

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* In the terms of conventional tapping notation the two systems are of the same intensity but when compared on a physiological basis the full-spiral system must be considered to be of greater actual intensity since it constitutes a greater drain on the latex system of the tree. The practice of measuring "intensity" of tapping in terms of amount of bark removed is in fact of little value when tapping systems with *different types* of tapping cuts are to be compared.

been noted that this effect is lessened by periodic rest during the growing season. Additional evidence of the restriction of translocation is provided by girth measurements below the tapping cut which show an even greater retardation of growth than is found above the tapping panel. The bulging of the tapping panel which is often noticeable above the cut is likewise an indication of the effect of partial ringing.

With regard to older trees less evidence is available. Sharp (1937) has found that the bark renewal at the base of the tapping panel was retarded 15-18 per cent in mature seedlings by tapping systems employing two half " V " cuts, one on either side of the tree. It may be assumed that the effects of double-cut systems resemble those of full-spiral tapping. It appears however that the effects of ringing will be ameliorated as trees increase in age. The normal flow of translocation is, it is believed, slower in old trees and this may be an important factor reducing the effects of ringing. Another factor operating in the same direction is probably the increased thickness of bark. It has been suggested that the greater vertical distance between the top and bottom of the tapping cut also tends to reduce interference with translocation in large trees but, until a detailed study of the path of translocation has been made, no evidence can be advanced on this question.

It may be noted that in practice ringing may be temporarily discontinued when the tapping cut reaches the base of the tree and is gradually shortened (see practical notes in Appendix I).

Conclusions

The experimental results show that full-spiral fourth-daily tapping (S/1,d/4,100%) has generally resulted in greatly increased crop and a considerable economy in tapping cost. The size of the tapping force has been reduced by 25 per cent.

The growth of trees tapped on full-spiral cuts has been less than in alternate-daily tapping on half-spiral cuts. This retardation of growth is the only serious consequence of full-spiral tapping which has been observed during the present experiments. An examination of the growth data has led to the following conclusions:—

(1) The observed retardation of growth of trees tapped S/1,d/4,100% is associated with the increased yield of latex obtained by this system. It must be emphasised however that no quantitative relationship can be suggested between latex yield and potential growth (see footnote p. 11).

(2) There is evidence however that the growth of *young buddings* was retarded by full-spiral tapping to an extent which

cannot be explained by increased yield alone and that this effect was ameliorated by rest.

(3) The growth of older trees was affected to a smaller extent.

(4) It is pointed out that all tapping systems retard growth to some extent and it is possible that improvements in planting material and methods of cultivation may in the future justify the adoption of tapping systems which retard growth to a greater extent than the S/2,d/2,100% system.

On the basis of these facts it is concluded that full-spiral fourth-daily tapping (S/1,d/4,100%) is not suitable as a *permanent* tapping system for young and small buddings on account of the retardation of growth. If the intensity of tapping is reduced more satisfactory growth is however obtained. Modification of the system in this way would not affect the economy in tapping cost which appears to be the greatest merit of full-spiral tapping. None the less, greatly increased yields can be obtained for a number of years (see Table I, Experiments 47 and 42) by continuous full-spiral tapping.

Fewer experimental results on the effect of full-spiral tapping on older trees are yet available but it is known that the growth of larger trees is not retarded to the extent found in very young areas, and it is not unlikely that as these investigations progress S/1,d/4,100% tapping will be proved suitable as a permanent tapping system for well-grown high-yielding areas. It would therefore be wrong to conclude on the basis of the results of the present experiments on young buddings that S/1,d/4,100% tapping is merely a convenient short-term policy in times of high release or labour shortage. Its value in this direction as well as the attendant danger when applied incautiously to young trees is however recognized.

At the present time the need for caution and careful supervision cannot be over-estimated, and tapping policy should be reviewed frequently in the light both of the observed effects of the system in the field and of the future results of the present series of investigations. If the practical recommendations accompanying this paper are followed it is considered that no undue risk will be involved and that considerable economic benefit may result from the introduction of the system.

Acknowledgments

The Institute is especially indebted to Socfin Company for providing much valuable information based on extensive practical experience of full-spiral tapping.

The experiments described in this paper were commenced before the writer joined the staff of the Rubber Research Institute and he is much indebted to the members of the Botanical Division staff who were responsible for the initiation of these investigations, especially Mr. C. E. T. Mann, Head of the Division, Mr. E. R. Guest who, prior to his departure from Malaya in June 1940, was in charge of tapping investigations and Mr. K. N. Kaimal who has carried out the oldest experiment on seedling trees (Experiment 47) since its inception in 1936. For the supervision of work at the Institute's Experiment Station since January 1940 thanks are due to Mr. J. H. Tovey.

Many of the experiments described in this paper have been carried out on estates and it is a pleasure to acknowledge the valuable co-operation in this work of Dr. W. B. Haines, Mr. P. Paxton Harding, Mr. M. E. Wright and Dr. R. J. Chittenden.

The statistical analyses have been carried out by Mr. H. Fairfield Smith who also collaborated in designing the experiments and developing methods of recording.

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APPENDIX I

FULL-CIRCUMFERENCE TAPPING IN ESTATE PRACTICE

The information now available makes it possible for more detailed practical advice on full-spiral tapping to be given than has been possible hitherto. The recommendations now made are based both on the results described above and on the experience of estates.

A. Types of Tree suitable for Full-Spiral Tapping

1. *Continuous tapping.* It is recommended that *continuous* full-spiral tapping be attempted only on trees in good condition which are considered able to stand up to S/2,d/2,100% tapping. This applies equally to seedling and budded rubber trees. It will be seen from Table I that clones vary greatly in their response to continuous full-spiral tapping. Well grown areas of high-yielding clones usually respond well.

It is advisable not to open young trees on full-spiral cuts until they reach a girth of 24 inches at the level of commencement of tapping.

Trees previously tapped should be examined carefully to ascertain whether full-spiral cuts can be employed without tapping unduly thin renewed bark. When half-spiral tapping has been in progress for a lengthy period the bark situation may make full-spiral tapping impracticable. If half-spiral cuts, already well down the panel, are extended the most serious difficulties may arise only after a new panel has been opened. **It is therefore important to look well ahead when deciding if full-spiral tapping can be adopted satisfactorily in areas previously tapped on shorter cuts.**

2. *Tapping at reduced intensity.* Such systems as S/1,d/4,6m/9,67% may possibly prove satisfactory on areas which do not come up to the standard required for continuous tapping. When the size of trees on such areas increases it may be possible to tap at 100% intensity.

B. Tapping Cut

1. *Time of opening.* It is not advisable to open cuts during or immediately after wintering since at this time the trees are least able to withstand the strain imposed by tapping.

2. *Direction and slope of cut.* A spiral* cut from high left to low right.

The angle of full-spiral cuts must be sufficient to prevent spilling of latex and to make the upper end of the cut at least 12-15 inches above the bottom end. It is not possible to lay down a definite ruling applicable to all trees but the following general recommendations may be made:—

Seedlings: 25° (approximately 4½ inches fall for each 10 inches of circumference). If the trees are very large this angle may be somewhat decreased.

Buddings: 30° (approximately 5¾ inches fall for each 10 inches of circumference). For high-yielding buddings with thin bark it may be necessary to increase this angle.

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* Except when existing "V" cuts are extended to a full circumference (see Sect. (4)) spiral cuts are normally used for full-circumference tapping. For very large trees with irregular trunks the extended V cuts may however prove of value.

3. *Height of cut.*

(a) If a new panel is to be opened on full-spiral the following heights are recommended:—

Buddings: The bottom of the cut to be 35-40 inches above the union.

Seedlings: The bottom of the cut to be 25-36 inches above the ground, depending on age.

(b) If it is proposed to change from half- to full-circumference tapping when a panel is partly tapped out the existing cuts should be extended into full-spiral cuts provided that a careful examination shows that unduly thin bark will not be tapped *at any time.*

4. *Extension of existing cuts.*

(a) *Spiral cuts.*—Half spiral cuts should be extended *upwards* until the top of the cut is immediately above the spout channel.

(b) *"V" Cuts.*—The left hand arm of the "V" should be extended upwards until its end is vertically above the upper end of the right hand arm. Such cuts are termed "extended-V cuts." Under no circumstances should both arms of a half-V-cut be extended equally so that they meet at the back of the tree.

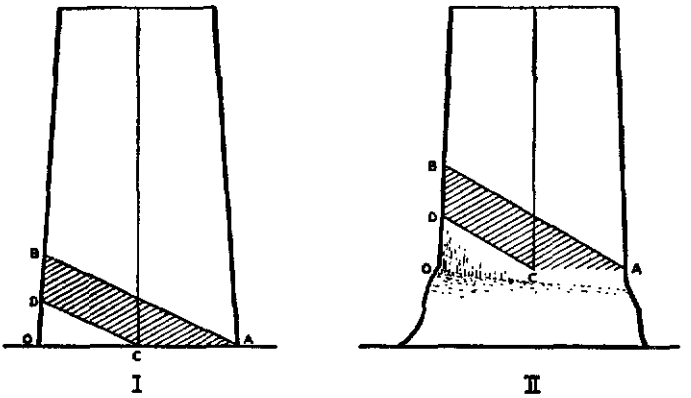

Fig. I. *Diagram of base of tapping panel of seedling tree.*
Fig. II. *Diagram of base of tapping panel of budded tree.*
Showing. Full-spiral cut AB at base of panel.
Half-spiral cut CD at base of panel.
The shaded area ABDC is excised by shortening the cut from S/1 to S/2.

5. *Modification of tapping cut at the base of the panel.*

When the bottom end of a full-circumference cut reaches the base of the tree (or approaches the union in the case of buddings) a much larger triangle of untapped bark will remain than is the case in half-spiral tapping (the triangle A.B.O. instead of the triangle C.D.O. in Figs. I and II).

On seedling trees it is most undesirable to leave this high yielding bark untapped and the tapping cut should be shortened to two-thirds or half circumference (see Fig. I). For trees 30 inches in circumference it will require a year or eighteen months to complete the panel on shortened cuts.

On budded trees on the other hand, this procedure (Fig. II) will result in a marked drop in yield and it is recommended only **when insufficiently renewed bark would otherwise be tapped on the second panel.** This situation is most likely to occur when bark consumption has been excessive or when full-spiral tapping has been introduced after earlier tapping on half-spiral on the same panel. If bark consumption and renewal are satisfactory in trees tapped on full-spiral cuts throughout their history it should be possible to abandon the first panel when it reaches two inches from the union and open a second full-spiral cut at 40 inches.

An alternative method of turning over the tapping cuts on budded trees is to open a half-spiral cut high on the panel above the lower half of the full-spiral cut and to continue tapping the upper half of the original cut. The two half-spiral cuts are tapped fourth-daily until the lower panel is completed. The upper cut is then extended to full-spiral. This method extends the bark cycle without reducing tapping intensity but the necessity for two tapping cups and spouts on each tree is a disadvantage.

C. Control of Tapping

The consequences of bad tapping become more serious when full-spiral tapping is introduced. The longer interval of time between tappings causes the bark on the tapping cut to become harder than in alternate-daily tapping and unless rigid control is exercised bark consumption may be excessive when tappers are new to the system. Furthermore the consequences of deep tapping and wounding are likely to be more serious than in tapping on half-spiral cuts.

When full-spiral tapping is introduced the number of tappers is reduced by 25 per cent and it should therefore be possible to exercise more efficient control of tapping without increasing expenditure in supervision.

(a) *Bark consumption.*—Assuming that measurements are made vertically, 5½ inches per annum is regarded as the maximum desirable rate of bark consumption in S/1,d/4,100% tapping. When bark is particularly hard the rate may initially be somewhat higher. In any area the rate of bark consumption should be carefully examined to ensure that there is time for adequate bark-renewal under the prevailing conditions. If renewal is not adequate, tapping intensity should be reduced. When full-spiral tapping has been preceded by a lengthy period of half-spiral tapping particularly close attention should be given to this question.

If budded trees are tapped continuously it will take 7 years to complete a panel in full-spiral tapping opened at 40 inches above the union. Allowing a year for tapping out the triangle of bark at the base of the panel (see B(5) above) it would be possible to avoid tapping renewed bark under 8 years.

It is usual to open seedling trees at a lower height, and if the first panel is opened at 25 inches and the second panel at 35 inches, tapping on renewed bark will not be necessary before approximately 7½ years of continuous tapping.

By improving tapping technique or reducing tapping intensity these periods for renewal may be considerably extended.

(b) *Depth of Tapping.*—It is important that full-spiral tapping should be less deep than is usual in half-spiral tapping. Variations in bark structure make it difficult for a rigid standard to be set but it may be mentioned that in certain areas it has been found advisable to leave 1.5-2.0 m.m. bark untapped in budded trees and at least 1.0 m.m. in seedlings.

(c) *Rotation of tasks.*—When tapping is prevented by rain the tasks due for tapping on that day should be tapped on the following day. In alternate daily tapping it is common practice not to modify the rotation of tasks on account of rain interference, but in fourth-daily tapping this procedure leads to tasks being untapped for so long a period that serious drying out of the cuts may occur.

D. Task Size

Tasks for full-circumference tapping should be between 67 and 70 per cent (i.e. two thirds or rather more) of the task size adopted for half-circumference tapping. If the stand is low, or the ground irregular, a slightly higher ratio is permissible, while for very large trees the task size should be still further reduced.

E. Latex Collection

A considerable amount of late dripping occurs in full-spiral tapping especially with certain clones (e.g. Tj. 1). To avoid a high proportion of low-grade rubber a second collection of latex in the early afternoon is often found to be economic. In localities where afternoon rain is frequent this is particularly important as the late drippings would otherwise be lost.

F. Safeguards in Full Circumference Tapping

(1) *Maintenance of trees in good condition.* It is particularly important that trees on full-spiral tapping should be kept in the best possible condition especially when they are young, by sound cultivation, manuring if necessary, and eradication of disease.*

Since full-spiral tapping places a greater strain on the constitution of a tree than more conservative tapping systems, it is possible that benefits of manuring will appear more rapidly.

(2) To detect deterioration *careful records should be kept* by measurement of:—

Girth increment

Bark renewal

Dry-rubber-content

If the rate of growth or bark renewal, of young trees especially, becomes unsatisfactorily low* the system should be modified in accordance with the suggestions made in Section G below. If d.r.c. drops considerably the same precaution should be taken.

(3) The strict control of tapping (see section C above) is however the most important of all safeguards.

G. Modification of Tapping System when Signs of Deterioration appear

(1) If signs of deterioration appear the intensity of tapping should be reduced.

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* The variations in the rate of growth and bark renewal, which occur from one part of the country to another, make it impracticable for definite standards to be recommended. Whether or not a satisfactory level is being maintained can however be judged by comparison with results for S/2,d/2,100% tapping in the same area.

Possible systems are: S/1,d/4,6m/9,67%, S/1,d/4,6m/75% or even S/1,d/4,5m/10,50%. Experiments with these variants of full-spiral tapping are now in progress.

(2) If deterioration has been so great that insufficient benefit results, even when the intensity of full-spiral tapping is greatly reduced, the tapping cuts should be shortened to half circumference. This situation is likely to occur only in areas which do not satisfy the standards set out in Section "A" above.

H. Estate Experiments

It happens not infrequently that managers are anxious to place in full-spiral tapping, areas of rubber regarding the suitability of which there is some doubt. Increasingly detailed information should make it possible for more definite advice to be given but it must always be expected that in certain cases the previous history of the trees or the local conditions will make it impossible to predict the effects of full-spiral tapping. In such cases it is recommended that a few tasks only should at first be placed on full-spiral tapping, so that a comparison between the effects of full and half-spiral tapping can be made under local conditions. Such simple experiments need not interfere with normal estate procedure. Their success depends on the tasks being laid out in such a manner that accurate comparison is possible.

APPENDIX II

Experimental Results: Comparison of Full-Spiral Fourth-daily Tapping (S/1,d/4,100%) with Half-Spiral Alternate-Daily Tapping (S/2,d/2,100%)

	Seedling Rubber					B.D.5					B.D.10			Tjirandji 1			
R.R.I. Experiment No.	47					34		46		6	42			7		8	
Type of Experiment (1)	S					S		S		T	S			T		S	
Locality	R.R.I. Experiment Station					Kerling District, Selangor		R.R.I. Experiment Station		Batu Anam, Johore	R.R.I. Experiment Station			Batu Anam, Johore		Bahau District, N.S.	
Age when first tapped on full-spiral (2) ..	7 years					7½ years		8½ years		8 years	6½ years			7½ years		7 years	
Duration of preliminary tapping on half spiral	nil					1 month		1 year		1 year	2 years			1½ years		2 months	
Initial Girth in inches (4)	25.5 in.					20.5 in.		21.1 in.		21.5 in.	21.9 in.			23.4 in.		22.3 in.	
Year of Experiment:—	1st	2nd	3rd	4th	5th	1st	2nd	1st	2nd	1st	2nd	1st	2nd	3rd	1st	2nd	1st	2nd
YIELD:																		
Yield of control trees, lbs./tree/annum	3.63	5.99	6.57	7.41	7.64	4.80	(3) 3.40	7.38	(3) 4.39	6.67	(3) 4.06	7.11	9.62	10.42	9.13	(3) 4.37	8.50	(3) 4.28
Relative Yield of S/1,d/4,100% System	**117**	**135**	**154**	**144**	**145**	**146**	**165**	**135**	**155**	**133**	**119**	**120**	**136**	**141**	**130**	**115**	**149**	**127**
Standard error	±10.3	±11.3	±14.3	±14.6	±13.6	±3.7	—	±4.2	—	±4.6	—	±8.2	±13.1	±13.1	±1.2	—	±5.0	—
Relative Tapping Cost	66	55	50	52	52	51	45	56	48	56	60	63	55	53	58	62	50	59
GROWTH:																		
Girth Increment of S/1,d/4,100% System inches/annum (4)	2.27			0.88		1.02	(3) 0.98	1.01	(3) 0.52	1.20	—	1.10		0.56	1.21	—	1.12	—
Relative Girth Increment	**92**			**97**		**55**	**59**	**63**	**54**	**63**	—	**57**		**57**	**67**	—	**43**	—
Standard error						±3.3	—	±4.0	±5.2	±7.0	—	±8.8		±7.6	±8.2	—	±2.5	—

	Tjirandji 16			S.R. 9			Ct. 88		Avros 50			Avros 71			Avros 256			Mixed P.B. Clones (5)	
R.R.I. Experiment No.	42			42			42		42			42			42			33	
Type of Experiment (1)	S			S			S		S			S			S			T	
Locality	R.R.I. Experiment Station			R.R.I. Experiment Station			R.R.I. Experiment Station		R.R.I. Experiment Station			R.R.I. Experiment Station			R.R.I. Experiment Station			Prang Besar Estate, Selangor	
Age when first tapped on full-spiral (2) ..	6½ years			6½ years			6½ years		6½ years			6½ years			6½ years			7½ years	
Duration of preliminary tapping on half spiral	2 years			2 years			2 years		2 years			2 years			2 years			2 months	
Initial Girth in inches (4)	18.7 in.			19.0 in.			22.1 in.		20.1 in.			23.4 in.			19.4 in.			23.9 in.	
Year of Experiment:—	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd	3rd	1st	2nd
YIELD:																			
Yield of control trees, lbs./tree/annum	8.52	9.82	10.17	5.27	6.46	7.13	7.81	9.61	10.96	6.70	8.94	9.26	7.61	9.05	10.69	3.58	5.34	5.49	5.28	9.54
Relative Yield of S/1,d/4,100% System	**97**	**120**	**107**	**97**	**107**	**111**	**182**	**174**	**145**	**132**	**139**	**119**	**117**	**144**	**139**	**68**	**114**	**149**	**113**	**106**
Standard error	±8.2	±13.1	±13.1	±8.2	±13.1	±13.1	±8.2	±13.1	±13.1	±8.2	±13.1	±13.1	±8.2	±13.1	±13.1	±8.2	±13.1	±13.1	±5.1	±5.1
Relative Tapping Cost	77	63	70	77	70	68	41	43	52	57	54	63	64	52	54	110	66	50	62	57
GROWTH:																			
Girth Increment of S/1,d/4,100% System inches/annum (4)	1.13		0.82	0.92		0.98	0.86		1.08	1.27		1.32	1.83		1.96	1.54		1.03	1.51	0.80
Relative Girth Increment	**69**		**68**	**85**		**105**	**47**		**62**	**78**		**90**	**76**		**86**	**87**		**71**	**80**	**100**
Standard error	±8.8		±7.6	±8.8		±7.6	±8.8		±7.6	±8.8		±7.6	±8.8		±7.6	±8.8		±7.6	±6.6	±6.6

RELATIVE YIELD = Yield of trees tapped S/1,d/4,100% expressed as a percentage of the yield of control trees tapped S/2,d/2,100%

RELATIVE TAPPING COST = Tapping cost per pound of rubber for S/1,d/4,100% tapping expressed as a percentage of the tapping cost for S/2,d/2,100% tapping.

RELATIVE GIRTH INCREMENT = Girth increment of trees tapped S/1,d/4,100% expressed as a percentage of the girth increment of control trees tapped S/2,d/2,100%.

Footnotes:

(1) Type of Experiment — S = "Single-tree plot" experiment (results based on individual tree records);
T = "Full-task" experiment (results based on task yields)

(2) The age of buddings is taken from the date of budding.

(3) Results for six months only.

(4) Girth measured *above* tapping panel.

(5) The clones in Experiment 33 are:—P B.23, 86, 183 and 186 and S.R.9. There are in equal number of tasks of each clone.