Physiological Changes in Hevea Trees under Intensive Tapping

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The incidence of dryness becomes greater when the tapping intensity is increased. In these experiments employing intensive tapping systems, the frequency of tapping played a more important role than the length of cut in inducing dryness, but the combination of both increased frequency and lengthening of the cut resulted in a very severe incidence of dryness. Heavy exploitation resulted in a decrease in the volume, rubber content and total solids of latex.

Dry and normal bark tissues were compared, carbohydrates did not seem to be depleted. However, the levels of protein nitrogen and per cent nitrogen were lower in dry than in normal bark tissues. The possible cause of dryness is discussed in relation to the senescence of phloem and laticiferous tissues.

The malady of tapped *Hevea* trees known as 'brown bast' which renders the affected trees partially or completely non-yielding, has been recognised for fifty years. In this condition a part or whole of the tapping cut ceases to yield latex and there is a characteristic grey or brown discolouration of the inner phloem region of the tapping cut. At a later stage some of the affected trees may show extensive meristematic activity which, in severe cases, results in extreme deformation of the entire trunk, rendering further tapping impracticable.

Studies on the onset of dryness have been difficult to conduct in the field because of the impossibility of forecasting which trees would go dry in a given planting. Compilation of complete case histories of every tree is very laborious. The alternative approach adopted was to induce deliberately dryness in healthy trees by the artificial interruption of phloem transport (CHUA, 1966a, and b). However, CHUA (1966a) had indicated that the results from phloem interruption might not reflect the physiological changes that occurred during the onset of the disorder in the field. It has been observed that intensive tapping causes a high proportion of the *Hevea* trees to go dry. In the present investigation the method of inducing dryness in the trees has been to tap the trees intensively. Physiological changes in the tapping panels were observed to determine the possible cause of dryness in trees which do not display foliar nutrient deficiency symptoms or evidence of parasitic infection.

The objects were: (i) to determine a suitable method of inducing dryness in the field; (ii) to compare the levels of carbohydrates nitrogen and protein nitrogen in the bark of yielding and non-yielding tapping panels; and (iii) to investigate further the possible relationship between senescence of phloem and laticiferous tissues of tapping panels and excessive latex drainage as suggested by CHUA (1966b).

MATERIALS AND METHODS

Experiments were carried out on six clones (BD 5, Tjir 1, Gl 1, RRIM 501, PR 107 and PB 86) in Field 37 of the Rubber Research Institute of Malaya Experiment Station. Four tapping systems were applied on an average of 25 trees per clone per treatment. The tapping treatments were:

(A) S/2.d/2.100%
(B) S/2.d/1.200%
(C) S/1.d/2.200%
(D) S/1.d/1.400%

Treatments were assigned to trees at random. Observations were carried out to deter-

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TABLE 1. PERCENTAGE OF TREES WHICH WENT AND REMAINED TOTALLY DRY DURING 18 MONTHS UNDER FOUR SYSTEMS OF TAPPING

Tapping system	BD 5	PB 86	PR 107	RRIM 501	Gl 1	Tjir 1
(A) S/2.d/2.100%	0	5	2	0	4	8
(B) S/2.d/1.200%	0	17	6	21	48	29
(C) S/1.d/2.200%	0	13	6	21	28	4
(D) S/1.d/1.400%	0	40	29	25	50	21

mine which tapping system gave the highest incidence of dryness.

Bark from partially or completely dry panels of trees tapped S/1.d/1.400% were excised and analysed for comparison with that of normal bark of trees tapped on the control system, *i.e.* S/2.d/2.100%.

The amounts of starch and of total soluble sugars in the bark were determined by modifications of the methods of McCready *et al.*, (1950).

The total nitrogen was determined by the usual micro-Kjeldhal method. The total soluble protein was determined by the use of Biuret reagent.

Bark samples of dry trees were taken, fixed in formalin-aceto-alcohol, embedded and sectioned. The sections were stained with safranin.

RESULTS

Lengthening the cut resulted in fewer cases of dryness than doubling the frequency of tapping in most clones (*Table 1*). Increasing both the frequency of tapping and the length of cut gave the highest incidence of dryness. No dry trees have been found in BD 5, which have a very poor yield. Clone Tjir 1 was less affected by the lengthening of the tapping cut than most of the other clones but did not tolerate the increase in the frequency of tapping. Clone PR 107 could tolerate either the increase in frequency of tapping alone or the increase in the length of the cut alone but not the combination of both.

The volume of latex, its dry rubber content and its total solids content were measured for trees tapped S/2.d/2.100 and S/1.d/1.400%. The results are plotted in *Figures 1*, *2*(*a*) and (*b*). The volume of latex per tapping, the mean d.r.c. and the mean total solids were less for trees tapped S/1.d/1.400% than for those tapped S/2.d/2.100%. *Figure 3* shows the yield of dry rubber in grams per tree in tapping per month, that of trees tapped S/1.d/1.400% was initially higher than that of trees tapped S/2.d/2,100% but later fell markedly below the latter. The volume of latex in litres per tree per month shows only a small drop in trees tapped S/1.d/1.400% compared with those tapped S/2.d/2.100% as shown in *Figure 4*. This indicates that the reduced yield of dry rubber per month can be attributed mainly to the lower d.r.c. of the latex on S/1.d/1.400% tapping. The quantity of serum solids lost per tapping can be calculated from the difference between the total solids and dry rubber contents of the latex. The weight of serum solids lost per tapping on each system is given in *Figure 5*, there is little difference between the two systems. Whereas the weight of serum solids lost per month is much greater in trees tapped S/1.d/1.400% than in those tapped S/2.d/2. 100% (*Figure 6*).

The results of bark analyses are given in *Table 2*, from which it can be seen that there was no difference in the amount of total soluble sugar in normal and dry tissues.

The average amount of starch present in the yielding and the non-yielding tissues did not also differ much. The non-yielding bark, however, was found to contain less nitrogen than the yielding bark. Dry bark contained less protein than the yielding tissues.

Histological sections of normal and dry bark were prepared. A photo-micrograph of a section of the normal yielding bark shows the sieve tubes and latex vessels are arranged in

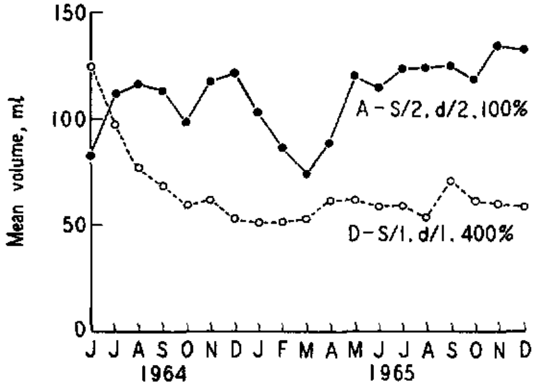

Figure 1. Volume of latex (ml) per tree per tapping.

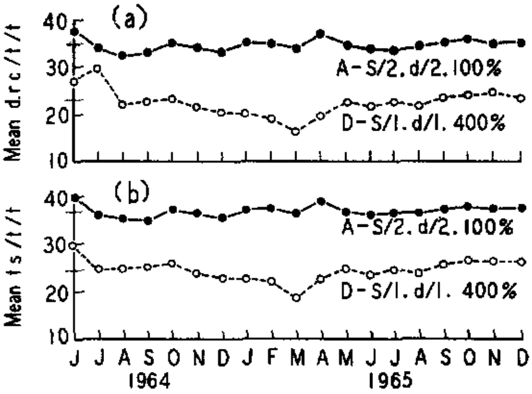

Figure 2(a). Mean dry rubber content (%) of latex.

Figure 2(b). Mean total solids content (%) of latex.

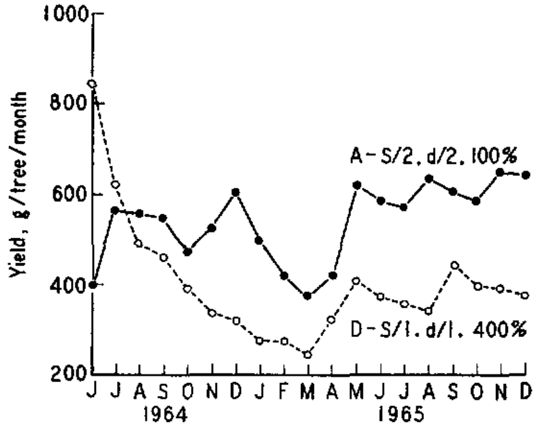

Figure 3. Yield dry rubber (g) per tree in tapping per month.

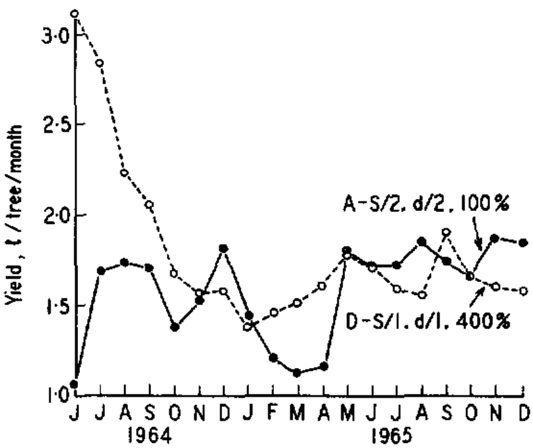

Figure 4. Volume of latex (l) per tree per month.

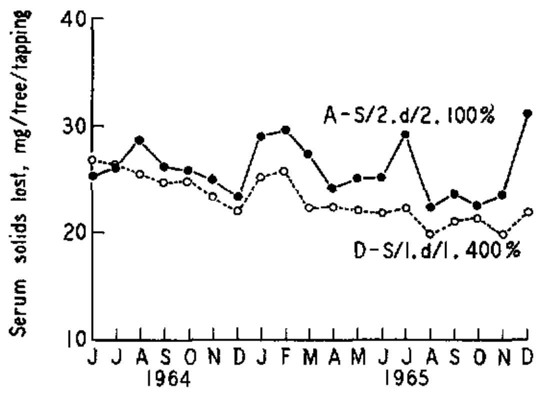

Figure 5. Serum solids (mg) lost per tree per tapping.

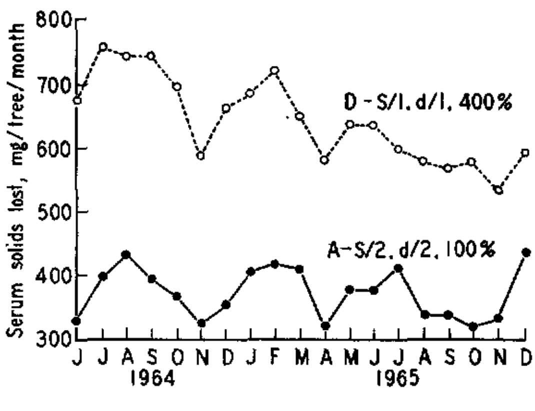

Figure 6. Serum solids (mg) lost per tree per month.

an orderly manner as in *Figure 7*. When *Figure 7* is compared with *Figure 8* which shows a section of the non-yielding bark, it is seen that the sieve tubes and latex vessels had become highly disorganised. Stone cells and tannin cells increase in number in the affected bark.

DISCUSSION

Many workers previously postulated that dryness of *Hevea* trees in tapping was a result of deficiencies in assimilates, especially carbohydrates. Analyses for the total soluble sugars and starch present in 'dry' and normal bark have shown that carbohydrates were not deficient (*Table 2*), confirming the findings of D'AUZAC AND PUJARNISCLE (1960) who showed that neither repeated tappings on the same morning nor daily tapping over a whole year, nor the cutting off of the leafy crown resulted in any fall in the levels of carbohydrates in the bark. In ring-barked *Hevea* trees, the carbohydrates were not depleted except for starch during the later stages of dryness (CHUA, 1966a and b).

Since carbohydrates are not deficient, yet the incidence of dryness increases with more frequent tapping, presumably some other essential components are depleted during intensive tapping. *Figures 1* to *4* indicate a relationship between the high incidence of dryness and excessive withdrawal of latex. Trees intensively tapped (S/1.d/1.400%) have much more serum solids lost per tree per month—mainly proteins and RNA—than trees tapped on S/2.d/2.100% (*Figure 6*). The proteins could be enzymes required for the proper functioning of the latex vessels. The draining of RNA would interfere with protein synthesis.

The fall in protein (*Table 2*) is a further indication of either a lack of protein synthesis or its breakdown. Since proteins provide the necessary enzymes, which control all the reactions of the cell, any serious disruption of protein synthesis in the cell will result in a loss of functions and ultimately death. The fall in the amount of protein in the bark could cause the latex vessels to become senescent and non-functional. The low d.r.c. and low total solids of latex obtained from intensively tapped trees may be a result of excessive withdrawal of essential compounds from the laticiferous tissues, which will also reduce the rate of replacing the lost compounds. The low incidence of dryness in trees under 100% tapping intensity indicates that they have the capacity and sufficient time to replace materials drained out.

From the photomicrograph in *Figure 8*, it is seen that there is an internal breakdown in the tissues of dry trees where there is a general disintegration of cellular organisation of the latex vessels and sieve tubes. The breakdown in the sieve tubes and the development of stone

TABLE 2. AVERAGE CONTENTS OF TOTAL SOLUBLE SUGARS, STARCH, NITROGEN AND SOLUBLE PROTEIN IN NORMAL YIELDING AND DRY BARK TISSUES

Item	Normal yielding tissue (S/2.d/2.100%)	Dry bark tissue (S/1.d/1.400%)	S.e. of Mean	Min. sig. diff. (p=0.05)
Total soluble sugars (μg/g of fresh bark)	20.5	20.9	±2.45	7.3
Starch (μg/g of fresh bark)	136.9	133.9	±7.94	24.1
Nitrogen (% of fresh bark)	0.82	0.68	±0.015	0.04
Soluble protein (mg/ml of fresh bark extract)	5.15	4.26	±0.082	0.24

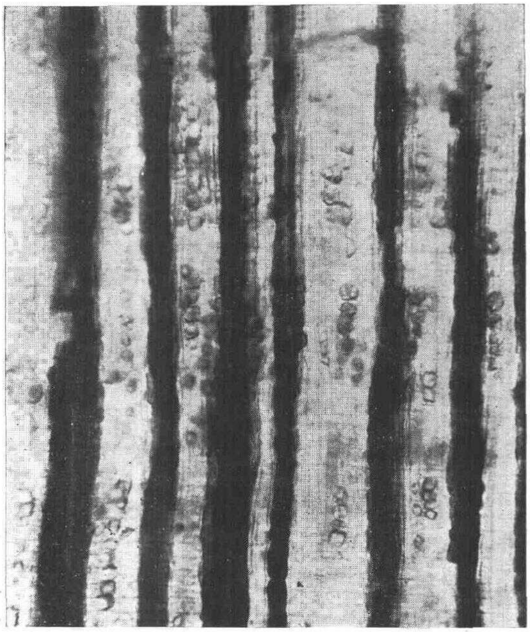

Figure 7. L.S. of bark showing normal latex vessels and sieve-tubes.

Figure 8. L.S. of bark showing disorganised latex vessels and sieve-tubes.

cells are indications of aging of phloem tissues as the result of the activity of the secondary meristem called cork cambium (MEYER *et al.*, 1960). *Figure 9* shows that the bark of dry trees may abscind and the flaking away of bark follow. The excessive drainage of serum solids in trees under heavy exploitation may cause these sieve elements to degenerate and become non-functional.

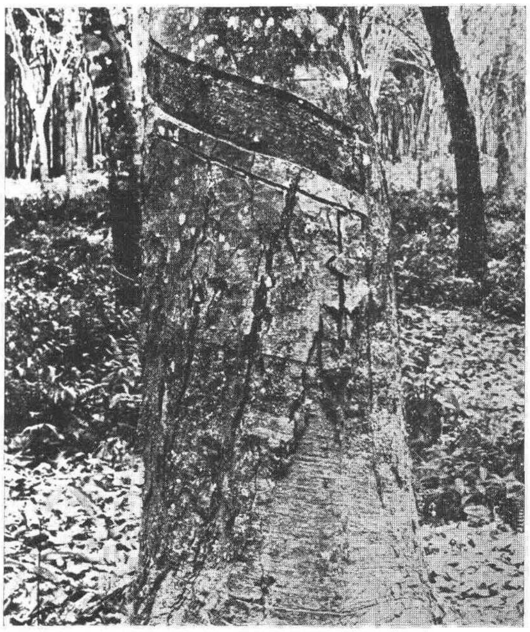

Figure 9. A non-yielding tapping panel showing abscission of bark.

It is generally assumed that upward movement of solutes occurs in the xylem and the downward movement in the phloem. Some exceptions to this do occur. However, it is generally accepted that upward movement of minerals and some organic compounds occurs chiefly in the xylem but some upward movement also occurs in the phloem. Downward movement of all kinds of solutes probably occurs almost exclusively in the phloem. In addition, considerable movement of water and solutes occurs over short distances outside the xylem and phloem. These various aspects of translocation have been discussed by SWANSON (1959) and BIDDULPH (1959). MEDVEDVE (1966) mentioned that the transport of substances in phloem, even over long distances, is transport by living protoplasm and is functionally connected with the active synthesis of proteins within the system. Since during intensive tapping the phloem tissues become disorganised, the translocation of essential compounds to this affected area will be disrupted and this will further accelerate senescence and death of the laticiferous tissues.

It has been observed that the renewed bark of dry trees will produce latex again when tapped. The latex comes from the new latex vessels produced (CHUA, 1967)—an observation which supports the theory that senescence of phloem and laticiferous tissues is a major cause of dryness in *Hevea*; but the interference with translocation is only temporary, the tree soon forming new phloem when the dead bark has sloughed off.

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