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Diurnal Variation in Latex Yield and Dry Rubber Content, and Relation to Saturation Deficit of Air

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The results of an experiment, in which the relation between hour of tapping and yield was investigated, indicate that the yield is maximum and constant between 20.00 hours and 07.00 hours; during the day, the yield decreases gradually to a minimum of 70% of the maximum yield around 13.00 hours. Tapping tasks of 3 hours' duration from 06.00 hours onwards result in 4–5% loss in yield per tapping compared to night tapping, but the number of days lost through rain is less. The d.r.c. at midday may be as much as 4 points higher than that obtained during the night. The diurnal variation in yield follows the variation in saturation deficit of the air closely and inversely.

Rubber trees tapped during the day are known to yield less latex than those tapped before daybreak. This phenomenon is of particular interest in Thailand where night tapping—often starting at 23.00 hours—is common practice. Compared with the more conventional early morning tapping elsewhere, higher yields per tapping are obtained this way; however, because of rain interference and poor control over tapping operations, the number of tapping days lost is usually high.

Little has been published on the relation between hour of tapping and yield. Three small experiments were carried out in Indonesia by DE JONG (1913–16); the results were inconsistent. A larger experiment was conducted by VAN LENNEP (1920) in which ten plots of fifty-eight trees were tapped S/4.d/1.100% at different hours from 05.30 hours to 17.30 hours. The results indicated a decrease in yield for trees tapped after 07.00 hours, to a minimum of 84% at about 13.00 hours, with a small increase towards 16.00 hours. MAAS (1925) quoted figures from an experiment in North Sumatra, which showed a decrease in yield to 85% at noon; the lower grades were higher during the day compared to tapping at 06.00 hours. DIJKMAN (1951) quoted yields at 09.00 hours and 11.00 hours as 96 and 85% respectively of the yield at 07.00 hours; according to him, the yield would be the highest early in the morning.

In Malaya, GOODING (1952) tapped eight trees alternately at 08.00 hours and 11.00 hours; four of the trees were tapped S/2.d/2, while the other four were tapped S/3.d/2. The latex yield at 11.00 hours compared with that at 08.00 hours was 15% lower for the half-spiral trees, and 25% lower for the third-spiral trees. In both cases, the d.r.c. at 11.00 hours was 1.5 points higher than that at 08.00 hours. DE JONGE AND WESTGARTH (1962) published results of a size-of-task experiment; they attributed the loss in yield per acre with increased task size to the fact that larger tasks were completed later.

Recently, NINANE (1967) presented data on the influence of time of tapping on yield. In one experiment, PR 107 buddings showed a decrease in yield from 100% at 06.00 hours to 86% at 14.00 hours, with a slight increase at 16.00 hours. In another experiment, the yield of PR 107 buddings decreased to 81% when tapped between noon and 14.30 hours, with no clear indication of recovery between 14.30 and 17.30 hours. The d.r.c. was about 2 points

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higher in the afternoon compared with 06.00 hours.

Since no further data on the relation between time of tapping and yield have been published, a more detailed experiment was considered useful.

DESCRIPTION OF EXPERIMENT

The experiment utilised 1800 fourteen-year-old trees at the Rubber Research Centre near Haadyai, and comprised three tasks of Tjir 1 seedlings and three tasks of Gl 1 seedlings. Tapping was S/2.d/2.100%; the yield level was about 1000 lb/acre/year. Each task was divided in six groups of fifty trees; each group was tapped within 30 minutes. The thirty-six plots in the experiment were rotated over the 'time of tapping' treatments to eliminate the influence of trees and tapper. There were three experimental periods.

In the first period of twelve tappings (5/11/66 – 15/12/66), tapping was done in six half-hour periods from 06.00–09.00 hours. The six tasks formed six replications; within each task, each group was tapped during each of the half-hour periods; the means over six tappings are therefore free of tree-influence.

In the second period of thirty-six tappings (14/1/67–13/4/67), tapping was done in eighteen half-hour periods from 03.00–12.00 hours. The three Tjir 1 tasks comprising eighteen groups of fifty trees formed one replication, the three Gl 1 tasks another. Tapping of a full task took 3 hours; the three tasks were rotated over the three 3-hour periods in cycles of six tappings, as follows:

Task		1st cycle*	2nd cycle*	3rd cycle*
Tjir 1	1	03.00 – 06.00	06.00 – 09.00	09.00 – 12.00
	2	06.00 – 09.00	09.00 – 12.00	03.00 – 06.00
	3	09.00 – 12.00	03.00 – 06.00	06.00 – 09.00
Gl 1	4	03.00 – 06.00	06.00 – 09.00	09.00 – 12.00
	5	06.00 – 09.00	09.00 – 12.00	03.00 – 06.00
	6	09.00 – 12.00	03.00 – 06.00	06.00 – 09.00

*Each cycle consisted of six tappings.

Within each cycle of six tappings, the groups were rotated over the half-hour periods. After eighteen tappings, each of the groups of fifty trees had thus been tapped at each of the half-hour periods; the means over eighteen tappings are therefore free of bias due to differences between trees, tapper and tapping days. There were two such periods of eighteen tappings.

The third experimental period (1/5/67–9/8/67) consisted of thirty-six tappings; tapping was done in thirty-six half-hour periods: from 10.30 – 04.30 hours. The tasks and groups were rotated in a similar way; there were no replications. The second and third experimental periods together covered 24 hours.

Collection

During the first experimental period, collection time was not staggered; consequently, the time between tapping and collection was shorter for the later tapped groups, resulting in a somewhat higher amount of cuplump. During the subsequent experimental periods, groups tapped at 03.00, 03.30 and 04.00 hours were collected from 06.30 hours onwards, while those tapped at 04.30, 05.00 and 05.30 hours were collected from 08.00 hours onwards, and so on. The average flow time thus varied from 205 – 165 minutes in each group of three half-hour periods.

Recording

The latex of each group of fifty trees was weighed separately. The amount of pre-coagulation in the collection buckets was appraised visually and scored in three classes. Samples for d.r.c. determination were taken on certain days. On the day following each tapping day, cuplump was collected; it was dried and weighed for each group of fifty trees.

Interference by Rain

Days on which rain interfered at any time were discarded, although part of the experiment was often tapped on such days. As a result, the real tapping intensity varied slightly between time treatments, mainly during the second experimental period, when tasks tapped from 03.00 – 06.00 hours were tapped less frequently than tasks tapped at a later hour.

TABLE 1. RESULTS OF FIRST EXPERIMENTAL PERIOD

Half-hour period (h)	Latex yield*	d.r.c. (%)	Cuplump*	Total yield dry rubber*
06.00	97.0	35.7	0.7	35.3
06.30	98.4	35.9	0.8	36.1
07.00	97.2	36.0	0.9	35.9
07.30	95.6	36.3	1.0	35.0
08.00	87.8	36.6	1.4	33.5
08.30	82.0	36.8	1.6	31.8

* g/tree/tapping

RESULTS

First Experimental Period

This period covered the hours of greatest interest (06.00 – 08.30). The latex yield, d.r.c. and lower grades (averaged over the six tasks) are presented in *Table 1.*

There are no significant differences in yield between the first three groups, but after 07.30 hours, the yield decreases. The results suggest that the decrease is more marked and starts earlier for the Tjir 1 seedlings as compared to the Gl 1 seedlings. The d.r.c. shows a gradual increase, rising by 1 point between 06.00 – 08.30 hours. The increase in cuplump is caused by the shorter flow time for the treatments which were tapped later. The latex yield of the Tjir 1 seedlings equalled that of the Gl 1 seedlings, but the yield of cuplump was about twice as high. The relation between hour of tapping, yield and d.r.c. is illustrated in *Figure 1.*

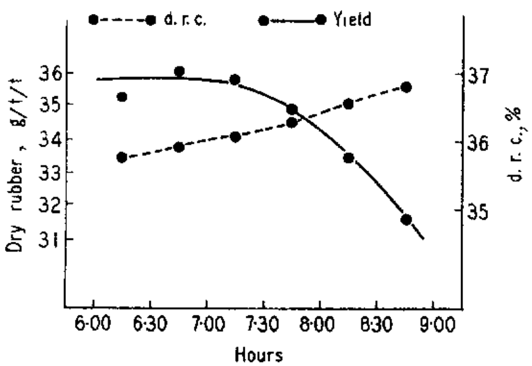

Figure 1. Latex yield and d.r.c. in relation to hour of tapping (first experimental period).

Second Experimental Period

This period covered the hours from 03.00 – 12.00 hours. *Table 2* presents the average latex yield, d.r.c., amount of cuplump and total yield for each of the half-hour periods. (For d.r.c., reliable means over three-hour periods only were obtained).

TABLE 2. RESULTS OF SECOND EXPERIMENTAL PERIOD

Half-hour period (h)	Latex yield*	d.r.c. (%)	Cuplump*	Total yield dry rubber*
03.00	92.7		0.9	33.8
03.30	93.1		1.2	34.3
04.00	92.4	35.7	1.4	34.3
04.30	93.8		0.9	34.3
05.00	94.5		1.1	34.6
05.30	91.7		1.3	33.9
06.00	92.0		0.8	33.6
06.30	91.7		1.0	33.6
07.00	89.8	35.8	1.2	33.2
07.30	87.0		1.0	32.0
08.00	83.6		1.2	31.0
08.30	79.2		1.4	29.6
09.00	75.2		1.2	28.7
09.30	71.3		1.3	27.5
10.00	69.1	37.1	1.5	27.0
10.30	67.3		1.4	26.4
11.00	64.3		1.5	25.4
11.30	62.1		1.6	24.8

*g/tree/tapping

The yield appears constant from 03.00 – 07.00 hours, after which it gradually declines to reach its minimum in the latest tapped groups (11.30 hours); at this hour, the yield is about 75% of the 'night yield'.

The results indicate that the difference between 'night' and 'day' yield is more pronounced in the Tjir 1 seedlings than in the Gl 1 seedlings, confirming the results of the first experimental period.

The average d.r.c. during the period 09.00–12.00 hours is about 1 point higher than during the night; the difference is again more marked in the Tjir 1 seedlings. The amount of cuplump shows a small increase within each 1½-hour period as a result of shorter time between tapping and collection. The figures suggest a higher amount of cuplump during the day than during the night, most of the cuplump being 'cup-cleanings'. A marked increase in pre-coagulation during day-time was observed and this, together with the higher d.r.c., explains the increased amount of 'cup-cleanings'.

Third Experimental Period

During this period, tapping was carried out from 10.30 hours until 04.30 hours the next morning.

Table 3 presents the mean yields over the whole period of thirty-six tappings; only means for 3-hour groups, corresponding to task means, are given.

TABLE 3. RESULTS OF THIRD EXPERIMENTAL PERIOD

3-hour period (h)	Latex yield*	d.r.c. (%)	Cuplump*	Total yield dry rubber*
10.30–13.30	52.6	40.5	1.1	22.4
13.30–16.30	55.4	40.0	1.0	23.2
16.30–04.30	67.6	38.3	0.6	26.5
04.30–22.30	81.4	36.9	0.7	30.7
22.30–01.30	84.0	35.8	0.8	30.8
01.30–04.30	83.2	35.4	0.7	30.2

*g/tree/tapping

The average yield during the period 10.30–13.30 hours is equal to that of the period 13.30–16.30 hours; a minimum yield of 21 g is obtained between 13.00 and 14.00 hours, after which the yield slowly increases. There are no differences in yield between 20.00 hours and 04.30 hours. The difference in d.r.c. between early morning and early afternoon is as much as 4 points. The somewhat higher amount of cuplump during the day is the result of more 'cup-cleanings' due to pre-coagulation and high d.r.c.

DISCUSSION

The relation between time of tapping and dry rubber yield was derived from the combined results of the three experimental periods. *Figure 2* shows the relation between hour of tapping and loss in yield, expressed as percentage of the 'night yield'. No differences in yield are found between 20.00 hours in the evening and 07.00 hours in the morning. After 07.00 hours, the yield gradually decreases until a minimum of about 70% of the 'night yield' is reached around 13.00 hours, after which the yield increases again. The relative decrease is therefore more pronounced than that found by VAN LENNEP (1920).

The d.r.c. follows a reversed pattern, and at noon can be up to 4 points higher than during the night.

The relative yield of a task in which tapping starts at a given hour depends of course on the time when tapping is completed. *Table 4* shows the relative loss in yield of 3-, 4- and 5-hour tasks when tapping starts at different hours in the morning.

Table 4 shows that tapping tasks of 400 trees from 06.00 to about 09.00 hours may result in a 4–5% lower yield per tapping compared to night tapping. However, the increased control over the tappers, the reduced loss of tapping days due to rain and the possibility of 'late

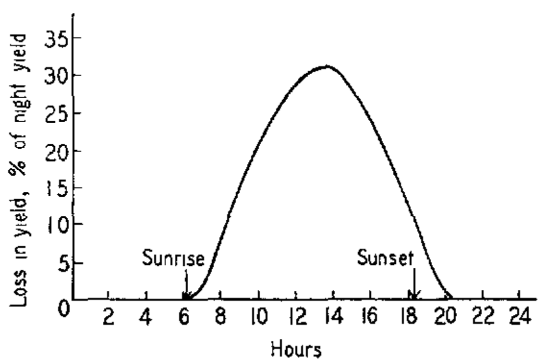

Figure 2. Diurnal variation in yield, expressed as percentage loss in yield.

TABLE 4. RELATIVE LOSS IN YIELD PER TASK, AS PERCENTAGE OF YIELD WHEN TAPPING IS COMPLETED BEFORE 07.00 HOURS

Tapping starts at (h)	3-hour task, %	4-hour task, %	5-hour task, %
05.00	1.0	3.2	5.8
06.00	4.3	7.2	10.0
07.00	9.6	12.4	15.0
08.00	15.6	18.1	20.3
09.00	20.8	22.9	24.5
10.00	25.4	26.7	27.4

tapping' when trees are wet, more than outweigh this small reduction in yield per tapping. This was confirmed at two rubber stations of the Department of Agriculture of Thailand, where the total monthly crop has increased since tapping was changed to 06.00 hours.

On some holdings in Thailand with unselected seedlings, tasks are considerably larger; tapping, starting at midnight, is often continued up to 07.00 hours. In such cases a change to tapping starting at 06.00 hours would be expected to result in a loss of 20% of the yield per tapping and it is not recommended.

Limitation of Experiment

It should be realised that in this experiment, as in those described by van Lennep and others, the same trees were tapped at different hours. This 'rotation' is required for an efficient design, eliminating tree bias. It is possible that the observed difference in yield between 'night' and 'day' tapping would gradually become less if trees were continuously tapped at the same hour.

To investigate this, a new experiment has been set up with fewer treatments without rotation of the groups over the time-treatments. Tree bias is reduced by having three replications and pre-treatment recording.

Tapping in Experiments

The difference in yield between trees tapped at 06.00 hours and at 09.00 hours is about 15%; therefore tapping the trees in a task always in the same order may seriously bias the results of clone trials and other experiments; hence in these experiments tapping should start at alternate ends of the task.

DIURNAL VARIATION IN YIELD AND ATMOSPHERIC CONDITIONS

Various authors have suggested that the lower yield during the day is the result of increased transpiration (DIJKMAN, 1951).

GOODING (1952) showed indirectly that the turgor of the trunk is much less at midday than during the early morning; during the day, water is under tension and when the vessels are opened, less latex is forced out; furthermore, owing to the tension on the water in the trunk, the latex would be unable to take up as much water; there would be less dilution, involving a smaller drainage area.

BUTTERY AND BOATMAN (1964 and 1966) showed by direct measurements that the hydrostatic pressures in the phloem exhibit diurnal fluctuations with a minimum in the early afternoon; the fluctuations are sensitive to weather conditions. These authors reasoned that increased transpiration of the leaves would result in a xylem tension, and — assuming that water can move freely between xylem and phloem tissues — in lower turgor pressures in the latex vessels; the lower pressure would result in less latex flowing out on tapping.

Recently, NINANE (1967a) discussed in detail the relation between yield and atmospheric conditions. He showed that transpiration of young rubber plants, being influenced both by the temperature and the relative humidity of the surrounding air, is highly correlated with the absolute saturation deficit of the air (NINANE, 1967b).

The saturation deficit of the air is the difference between the actual vapour pressure of the air and the saturated vapour pressure; the latter depends on the temperature (NINANE 1967a, *Table 1*), while the actual vapour pressure is equal to the saturated pressure multiplied by the relative humidity.

Hourly measurements of temperature and relative humidity were taken at the Rubber Research Centre, Haadyai, close to the field in which the experiment was carried out; the saturation deficit has been calculated from those observations for every hour during the period May – October 1967. During the night, when the relative humidity is about 95%, the saturation deficit is about 1 mm Hg; it increases rapidly during the day; the highest value observed was 23 mm. *Figure 3* shows the diurnal variation in saturation deficit (averaged over all days from May – October). The broken line in this graph represents the mean over the 108 days during this period on which no rain was recorded.

A comparison of *Figure 2* with *Figure 3* shows that the diurnal variation in yield per tapping follows closely the variation in vapour pressure deficit. It appears that the restoration of the yield in the late afternoon anticipates the reduction in vapour pressure deficit; the relative yield reaches the 'night' level at about 20.00 hours, at which hour the vapour pressure deficit is still 3 mm. A possible explanation is that the total yield of a tree depends not only on the turgor pressure in the vessels at the moment of tapping, but also on the atmospheric conditions during the period after tapping during which flow continues.

NINANE (1967a) suggested that the yield decreases sharply whenever the vapour pressure deficit reaches 8 mm; this is not confirmed by the experimental results. This author also found that the restoration of the yield in the afternoon lags behind the decrease in vapour pressure deficit; hence a vapour pressure deficit in the afternoon equal to that in the morning would correspond to a lower yield. Such a time lag between restoration in yield and decrease in vapour pressure deficit was not observed in the experiment.

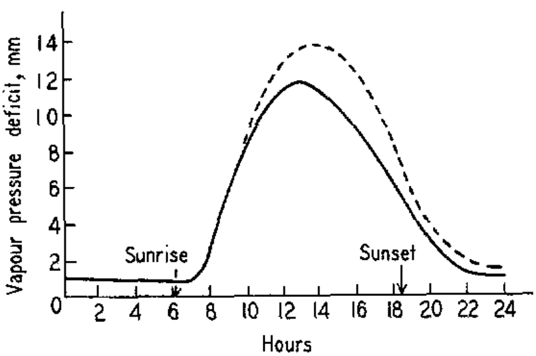

Figure 3. Diurnal variation in vapour pressure deficit of the air (Haadyai). Solid line represents average of all days from May to October; broken line represents average of days without rain.

The observations on turgor pressure by BUTTERY AND BOATMAN (1966) suggest that the pressure in the trunk is restored to the maximum 'night' value by 20.00 hours. The quick response of turgor pressure to atmospheric conditions was also evident during rain in the afternoon, when the reduction in transpiration immediately permitted a relaxation of the xylem tension and a partial restoration of the turgor in the trunk, before any significant reduction in leaf deficit occurred. This agrees with the experimental results, which show that the yield is restored to its maximum 'night' value at about 20.00 hours.

The marked increase in d.r.c. during the day could partly be explained by less dilution (GOODING, 1952); it seems likely however that the d.r.c. *in situ* is also higher during the day as a result of transpiration and subsequent tension on the water in the xylem.

Given the close relation between vapour pressure deficit and relative yield, one may expect smaller differences between 'night' and 'day' yield on days with a low saturation deficit (cool or humid days). Examination of the detailed experimental records shows that such is indeed the case.

Initial Flow Rate and Plugging Index

It would be of interest to know whether the lower yields during the day are caused by a lower initial yield or by a higher 'plugging index' (shorter flow time).

A number of flow curve observations was taken in regard to ten trees tapped at 12.00, 18.00 and 24.00 hours; they show that the initial flow rate is lower when tapping is done at 12.00 hours; no significant differences in flow time could be established.

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DISCUSSION

Chairman: Mr. C. W. Brookson

Mr. R.C. Carter asked whether a reversal of the order in which the trees were tapped on successive tappings would enhance yields. Mr. Paardekooper replied that he could give no reason why it should be so, but he nevertheless considered it to be good practice to reverse the order of tapping trees. Prof. G.E. Blackman suggested that, provided availability of water to the roots was not limiting, the main factor controlling transpiration would be solar radiation — which would be more informative even if more complicated and expensive to measure than atmospheric humidity. Dr. P.R. Wycherley said that significant correlations had been established between solar radiation, diurnal temperature range, the minimum atmospheric relative humidity by day (*i.e.*, the drop from near-saturation at night) and the saturation deficit at several stations in Malaysia. Water should be conserved by contour planting and silt pits, perhaps any effect of the ground covers in mature areas should be investigated.

Mr. Paardekooper said in reply to Mr. S.E. Chua that significant differences in yield between day and night tapping were found during the wintering period when transpiration was minimal due to the lack of leaves. He confirmed, in reply to Mr. E. Bellis, that *Figure 2* referred to the loss in yield of dry rubber (not of latex). He described how allowance was made for rain interference, either by omitting tapping altogether if rain fell early, or by discarding the results if rain fell during tapping.

Dr. J.B. Gomez referred to the low initial yields when the saturation deficit was large and suggested that the following sequence — large saturation deficit, reduced turgor pressure and lower initial flow rate — would lead to less shear and a lower plugging index. However, Mr. Paardekooper said that the observations (admittedly few) showed no change in the plugging index. If there was no difference in the plugging index, the differences in total yield between day and night tapping were dependent on the initial flow rate. Moreover, the plugging index was independent of the dry rubber content of the latex. He agreed with Dr. F. Ninane that either the plugging index or the initial flow rate or both might be involved, though the initial flow rate seemed to be the more important factor. Since the experimental trees were seedlings, a range of individual plugging indices was represented.

Dr. P. de T. Alvim remarked that the internal hydrostatic pressure, which could be measured as a 'negative pressure' by the 'pressure bomb' (SCHOLANDER *et al.* (1965), *Science*, **148**, 339), would seem to be important. His preliminary results with this method were in agreement with the data under discussion, the negative pressure of 3–6 atmospheres in the night rose to 20–25 atmospheres at noon. Since the transpiration rate seemed to be associated with the rate of latex flow, trial of anti-transpirations such as mercuric hydrochloride (which induced stomatal closure) would be interesting.