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*Some Factors Affecting Yield Response to Stimulation with 2-Chloroethylphosphonic Acid**

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Investigations showed that the minimum time required for ethephon to bring about incipient yield response was 5 h to 6 h after application of the stimulant. The order of response was influenced by the internal turgor of the laticiferous phloem tissues and external conditions such as temperature and relative humidity. The high diffusion pressure deficit values obtained in the afternoon probably reflect the existence of high water tensions in the xylem tissues. The lower responses observed during the day may be due to the withdrawal of water from latex vessels and other bark tissues by transpiration.

Ethephon applied at different sites around the trunk gave varying responses. Good responses were obtained when the stimulant was applied close to the tapping cut and at positions below the cut.

Trees repeatedly treated with ethephon for more than three years gave lower initial flow rates and reduced turgor pressures in the laticiferous tissues.

A number of factors are known to influence yield production in *Hevea*. These can be broadly grouped into factors associated with (a) genetics (b) exploitation (c) physiology and (d) climate.

Through breeding and selection it has been possible to recommend to rubber growers cultivars capable of producing a six-fold increases in yield over the past forty years[1]. One of the yield determinants is the number of latex vessel rings[2-5]. Other factors such as vigour, wind damage and disease resistance which influence yield have been reviewed by Wycherley[6].

Some of the exploitation factors are, the slope of cut[7], tapping depth[8] and tapping intensity[9].

The rate of plugging of latex vessels during flow is an important factor controlling latex yield. The simplest and widely studied method for measuring the rate in sealing of vessels is the ratio of the mean initial flow rate in millilitre per minute to the total yield volume in millilitre multiplied by hundred. This expression known as the plugging index has been shown to be a clonal characteristic. Yield stimulation is most effective with trees which show a high plugging index[10]. The other physiological requirement for ensuring higher yield is proper nutrition especially when the trees are stimulated with ethephon[11].

One of the major factors which influence the flow of latex is the time at which trees are tapped. It is well known that rubber trees tapped before day-break yield more latex than those tapped during the day. Van Lennap[12] observed fluctuations in yield from trees tapped on S/4.d/1 100% during 0530 h to 1730 hours. A fall in yield of 16% between early (before 0700 h) and late (1300 h) tapping of trees was observed.

* 2-chloroethylphosphonic acid, abbreviated as CEPA has been approved by the American National Standards Institute to be known as ethephon. Ethrel is used as a trade name for ethephon formulation.

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Other workers[18-20] reported fall in yields ranging from 4% to 25% from trees tapped during the afternoon. In a more recent study, Paardekooper and Sompong Sookmark[17] showed that in Thailand the differences between trees tapped before 0700 h and 1300 h amounted to about 30%.

Ninane[16] found that diurnal fluctuations in yield was closely related to atmospheric conditions. He showed that transpiration in young rubber was inversely correlated with the vapour pressure deficit (VPD) and influenced by temperature and relative humidity. A similar relationship between yield and VPD was observed by Paardekooper and Sompong Sookmark[17].

Although the physiology of latex flow before and after stimulation with 2,4-dichlorophenoxyacetic acid[13-16] and ethephon[21-23] has been studied in some detail, little work has been done on the following:

- influence of diurnal changes on the time and order of response to stimulation,
- minimum time required for ethephon to bring about incipient yield response,
- site of ethephon application on the extent of response, and
- physiological effects on long term stimulation with ethephon.

Investigations were carried out to obtain a better understanding of the extent of yield *response to stimulation as influenced by some* external and internal factors.

MATERIALS AND METHODS

All experiments were carried out on twenty to twenty-five-year-old budded trees of clones Tjir 1, RRIM 600 and RRIM 612. The trees were tapped on S/2.d/2 tapping system on *Panel C* or *D*.

Application of Stimulant

Ethephon, used in the form of Ethrel, was applied (10% a.i. in palm oil) onto a 3.8 cm band of scraped bark. To the control trees only palm oil was applied to the scraped area of bark. Flow rates were recorded by timed collections into calibrated containers.

Yield responses were worked by measuring the volume of latex for individual trees after flow had ceased.

Measurement of Temperature and Relative Humidity

Atmospheric temperature and humidity were measured directly using the Thermohydrograph.

Turgor Pressure

Turgor pressures were measured by the method described by Buttery and Boatman[24,25]. Capillary manometers were used to obtain pressure in the laticiferous tissues. Each manometer was quickly inserted into a hole made with a needle of similar diameter to that of the steel tube of the manometer. The latex flowed into the capillary tube and compressed the air within enabling the pressure to be calculated from the initial and final lengths of the air column in the tube.

Osmotic Pressure

The osmotic pressure was measured on drop samples of latex, using the Vapour Pressure Osmometer as described by Pakianathan[26].

Specific modifications of or additional to the above procedures for individual experiments are described separately.

PROCEDURES AND RESULTS

Effect of Diurnal Changes on Response to Ethephon Stimulation

Experiments were carried out to determine the minimum time required to bring about incipient yield response to ethephon stimulation. These experiments were carried out on separate occasions under two environmental conditions: first, during daylight (0630 h to 1830 h), when the turgor in the laticiferous tissues would be expected to be at its minimum and subjected to diurnal changes and, second, during darkness (1830 h to 0630 h) when the turgor pressure in the vessels is maximum and remains somewhat constant.

For the first experiment, sixty-two trees of clone Tjir 1, tapped on *Panel D* were selected. These were randomised on the basis of girth and pre-treatment yields into groups of four trees to obtain thirteen sets of trees. Two trees from each set were stimulated with ethephon while the other two served as controls. Stimulation was carried out from 0600 h and completed at 0630 h by three persons. The exact time of stimulant application for each set of trees was recorded.

The last set of trees (two treated and two control) which received ethephon at 0630 h were tapped immediately.

The yields obtained for these trees were taken as zero time of application. Tapping of each set of trees was regulated at half-hourly intervals from the time of stimulant application for the first 3 h and thereafter at hourly or two-hourly intervals until 12 h from the time of stimulant application. The yield of latex for each tree was recorded after flow had ceased.

The second experiment was carried out in the same field on another forty-eight trees of clone Tjir 1. The same procedures and treatments as described for the previous experiment were followed, except that stimulation was carried out between 1800 h and 1830 hours. The effects of ethephon stimulation on response to yield was recorded from 1830 h to 0630 hours.

Figure 1 shows the yield values obtained on ethephon-stimulated and control trees tapped at various times during daylight (0630 h to 1830 h). Each point in the graph represents a mean yield value of two trees. The control trees tapped during 0630 h to 0930 h showed a higher yield trend compared with yields obtained from trees tapped in the afternoon (1230 h to 1630 h). The trees tapped in the evening (1830 h) gave similar values to those obtained from early tapping (0630 h to 0930 h). The yields observed for the ethephon-stimulated trees tapped during daylight were

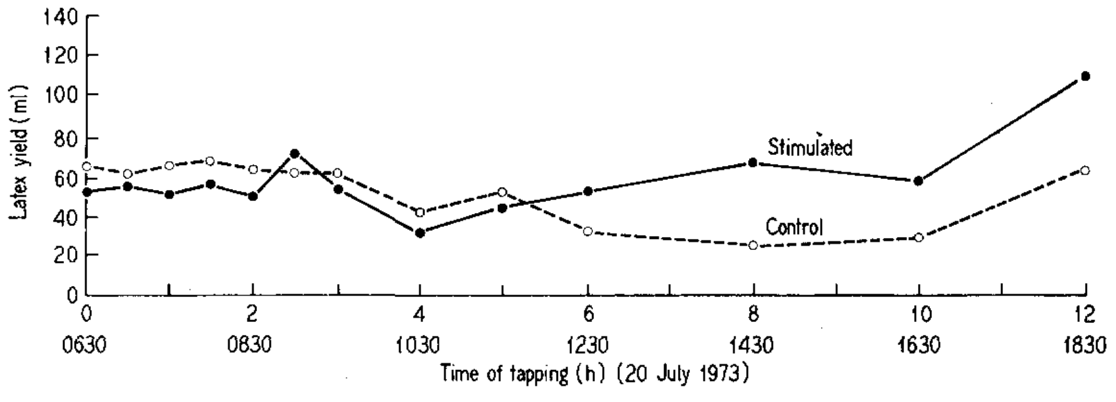

Figure 1. Effect of ethephon application on time of response during daylight.

Stimulant applied at 0630 h and trees tapped at successive time intervals and followed until 1830 h (12 h).

Control — same procedure except no stimulant was applied.

similar to those observed for the controls during the initial 5 h from the time of stimulant application, after which the yields were sustained until 1730 hours. Trees tapped 12 h from the time of application (1830 h) gave higher yields. The difference in diurnal yield trend between the control and ethephon-stimulated trees was marked in trees tapped during 1230 h to 1630 hours. This difference was due to a fall in yield levels in the control trees while the yields in the stimulated trees during this period were sustained.

Comparing the diurnal fluctuations in yields between the controls tapped during daylight *(Figure 1)* and those tapped during the darkness (*Figure 2*), it can be seen that generally trees tapped during darkness gave higher yields and showed less fluctuations than those tapped during daylight. A greater yield variation was observed on ethephon-stimulated trees during the initial 2 h to 3 h compared with controls *(Figure 2)*. A noticeable response to stimulation was observed on trees tapped 6 h after ethephon application and a further increase in response was observed 12 h from the time of its initial application.

Since the yield increase to ethephon treatment was only observed after 5 h from the time of application, the results suggested that a minimum time of 5 h to 6 h is required before ethephon stimulation could bring about incipient yield response. Further increases in yield were observed after 10 hours.

Diurnal Changes in Osmotic and Turgor Pressures

The diurnal changes in atmospheric temperature and relative humidity were recorded separately on the same day. *Figure 3*

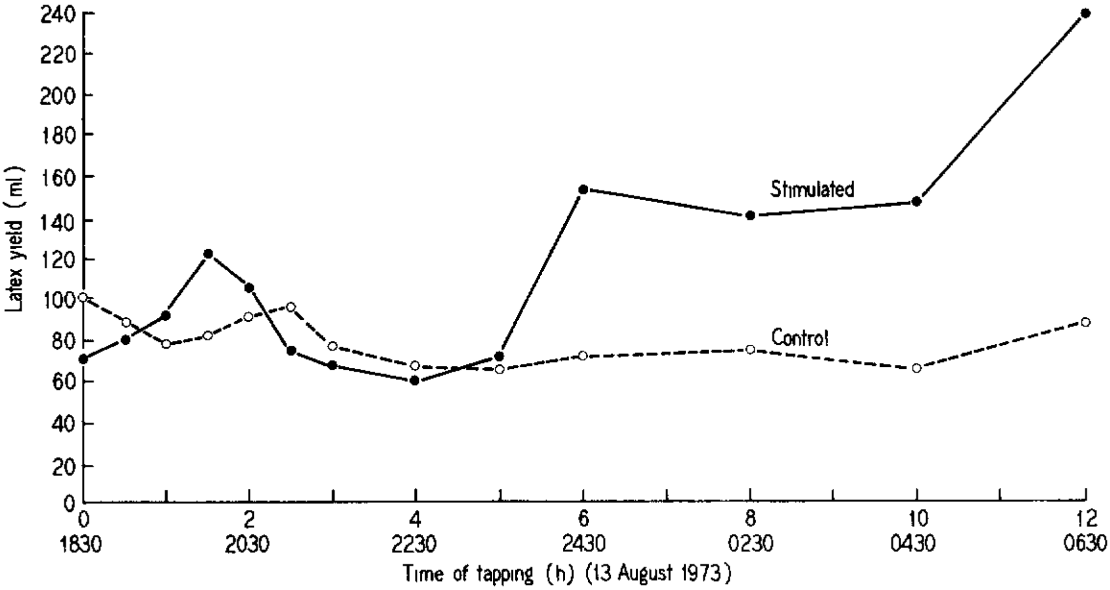

Figure 2. Effect of ethephon application on time of response during darkness.

Stimulant applied at 1830 h (0 h) and trees tapped at successive time intervals and followed until 0630 h (12 h).

Control — same procedure except no stimulant was applied.

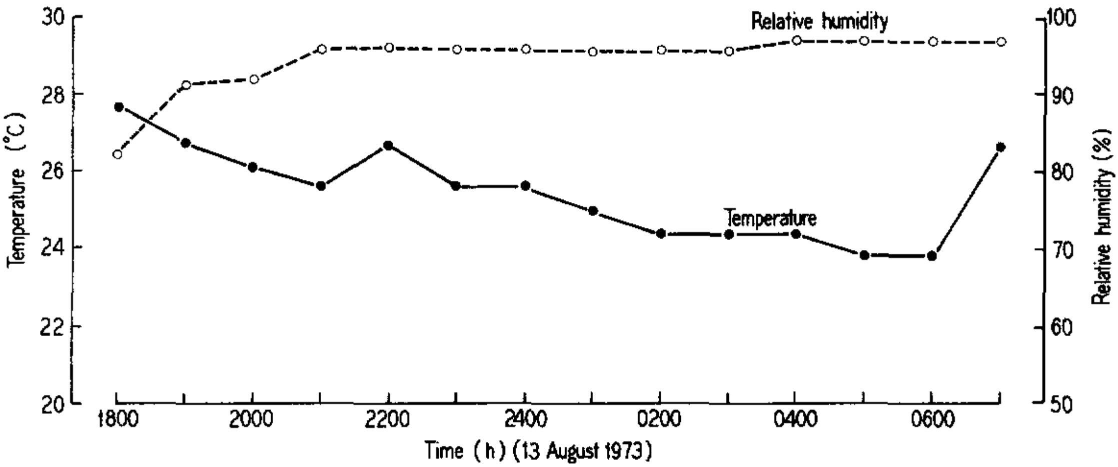

Figure 3. Diurnal changes in temperature and relative humidity during darkness.

shows that the diurnal changes in temperature and relative humidity during the 1800 h to 0600 h were not marked. The relative humidity at 1800 h was 82% while the temperature was 27.6°C. The temperature fluctuated between 23.9°C and 27.6°C and the relative humidity (apart from the 1800 h recording) fluctuated between 91% and 97%.

Recordings of temperature and relative humidity taken during the day showed marked fluctuations. The temperature at 0600 h was 22.2°C and gradually rose during the day reaching a maximum 32.2°C at 1500 h and thereafter fell gradually to 28.2°C at 1900 h *(Figure 4)*.

It can be seen in *Figure 4* that the relative humidity recorded at 0600 h gradually declined until 0900 h and subsequently fell rapidly reaching a minimum of 60% at 1500 h and rose again to 92% at 1900 hours.

In a separate experiment the osmotic pressure of the latex and the manometric pressure of the laticiferous tissues were measured on the virgin bark above the tapping panel on Tjir 1 trees. These results are given in *Figure 5*.

The osmotic pressure of latex measured during the day showed a very small but gradual rise during the course of the day. The net difference of 8.2 atmosphere was observed between the early morning (0530 h) and late evening (1600 h) values. However, the turgor pressures declined rapidly during the course of the day and reached a minimum of 5.7 atmospheres at 1600 h and gradually rose again to 7.3 atmospheres at 1900 h but did not recover to its original value of 9.75 atmospheres.

The diffusion pressure deficit values for each determination was obtained by taking the difference between the osmotic and the turgor pressures. It can be seen in *Figure 5* that at 0530 h the diffusion pressure deficit was only 0.3 atmosphere and increased during the course of the day to a maximum of 4.5 atmospheres at 1600 h and then declined to 3.1 atmospheres at 1900 hours.

Yield Responses in Relation to Site Application of Ethephon

The aim of this experiment was to determine whether ethephon application at different sites on the trunk in relation to the tapping cut could influence the time and order of response.

Two hundred and forty trees of Tjir 1 clone were selected for this experiment. Girth

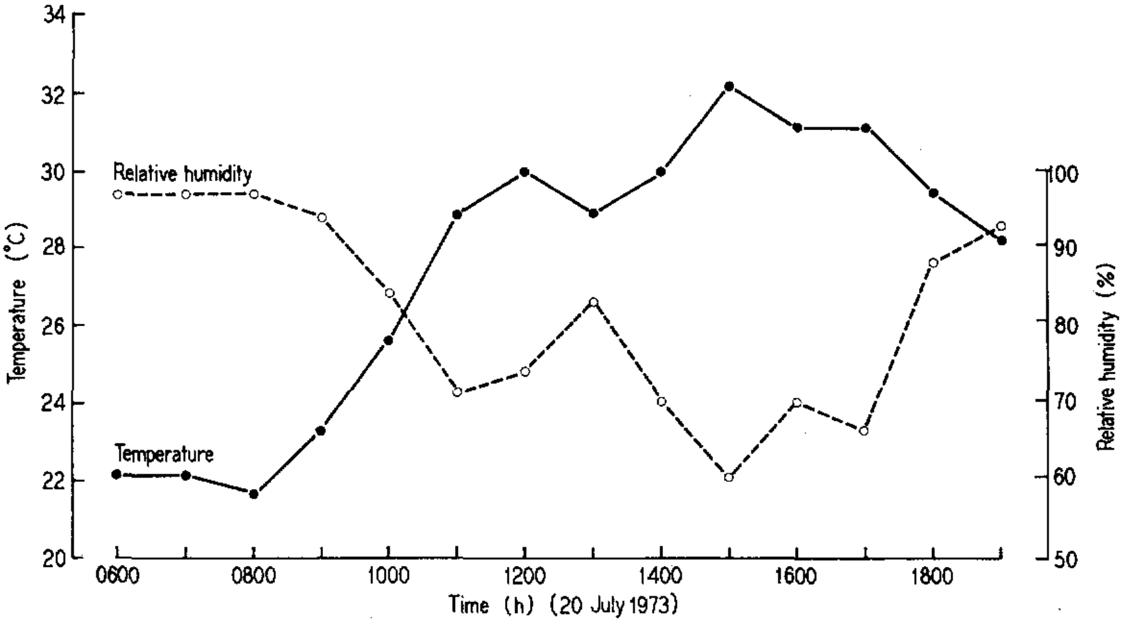

Figure 4. Diurnal changes in temperature and relative humidity during daylight.

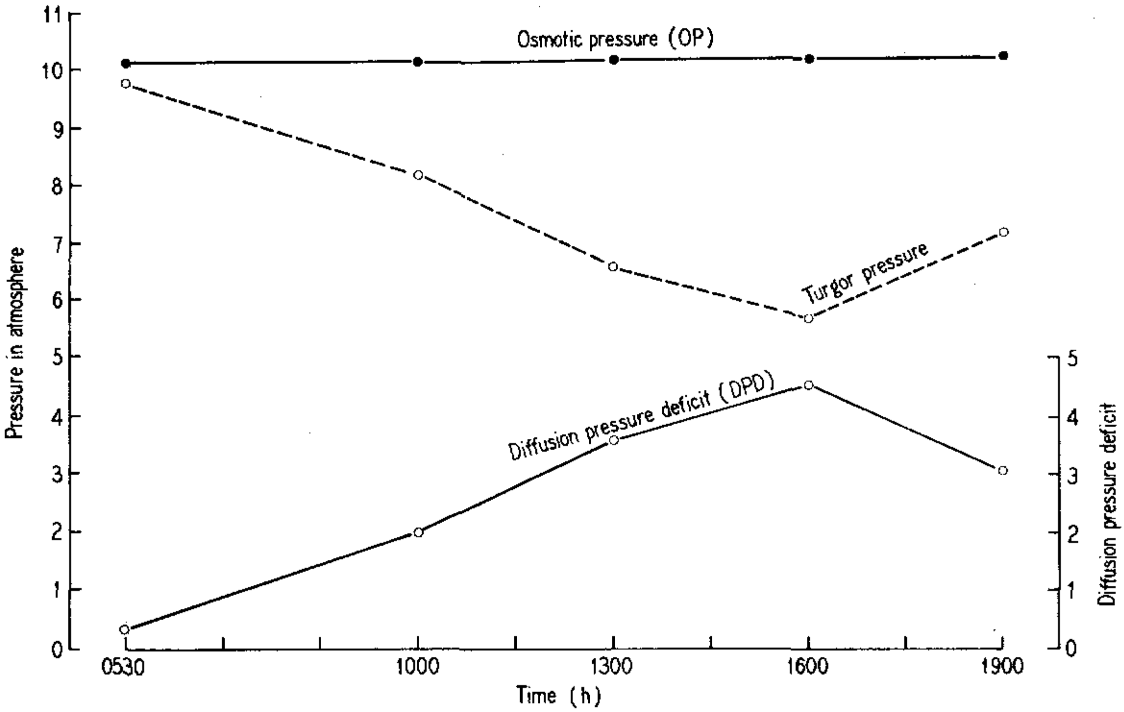

Figure 5. Diurnal changes in osmotic and turgor pressure and diffusion pressure deficit.

measurements and pre-treatment yields were recorded for each tree. The trees were then randomised for allotment to sixteen treatments. Ethephon application at different sites were 1.5 cm, 35 cm and 70 cm below the tapping cut and on the opposite side of the tapping panel. On the renewed and virgin bark, application was at 35 cm and 70 cm respectively above the tapping cut. The other eight treatments were identical except that only palm oil was applied to the scrapped bark. The treatment in relation to the cut are shown diagrammatically in *Figure 6.*

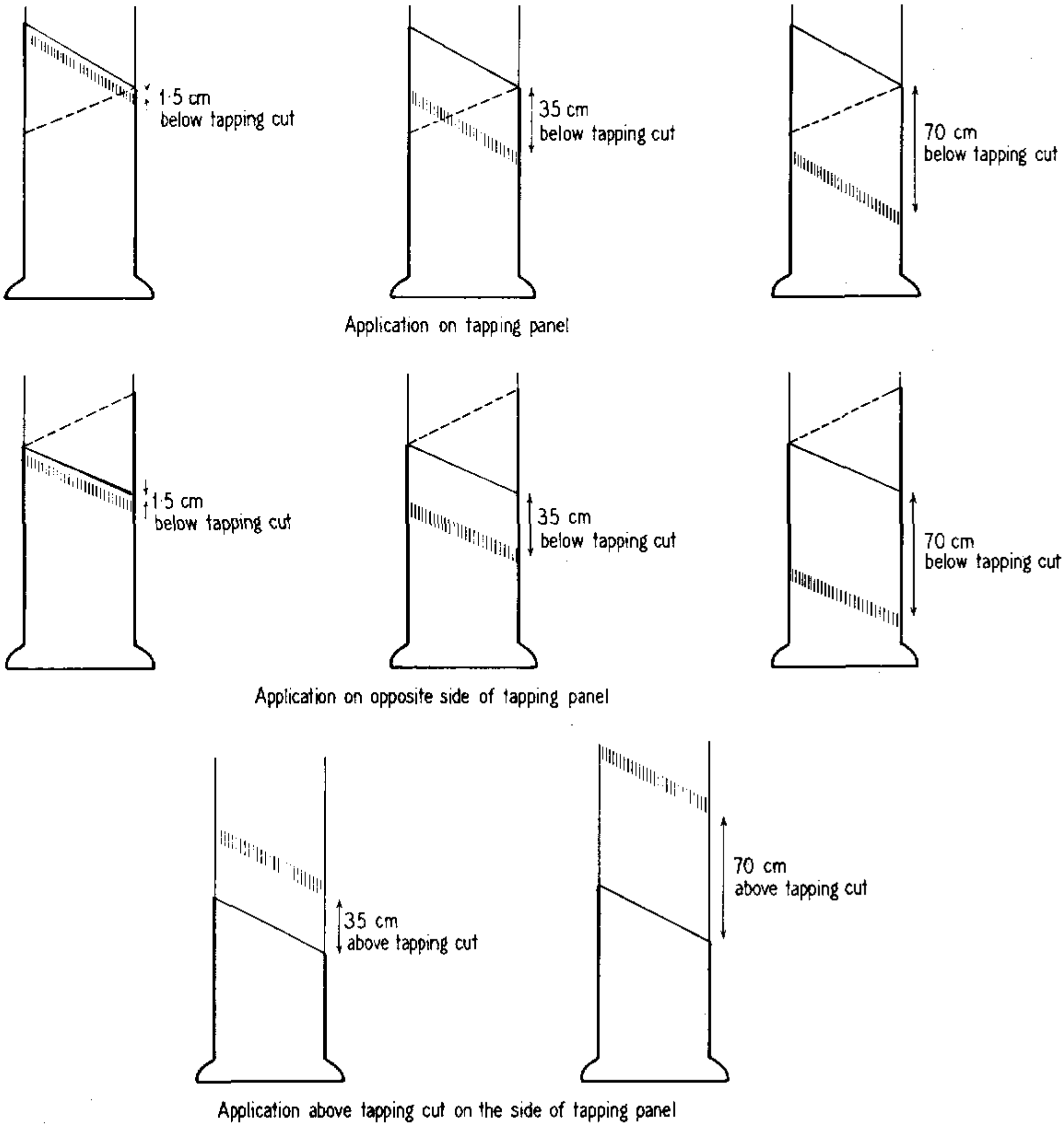

Figure 6. Diagrams indicate the sites (in relation to tapping cuts) on which ethephon was applied.

For convenience of measuring yield the trees were first tapped 18 h after application of ethephon. After 42 h and 90 h from the time of initial application the trees were tapped. The results are summarised in *Table 1.*

Apart from the treatment in which ethephon was applied 70 cm above the cut, all treatments gave marked yield responses when tapped 18 h after ethephon application. At all three tappings, ethephon applied close to the tapping cut (1.5 cm) gave consistently the best yield response, followed by treatments in which the stimulant was applied at 35 cm and 70 cm below the cut. Application of stimulant on the opposite side of the tapping panel generally gave lower responses than those applied below the cut. The order of response to ethephon applied 35 cm above the tapping cut was poor.

In comparison with the first tapping, all treatments on the second tapping (42 h after ethephon treatment) gave higher yields. The yields obtained on the third tapping (90 h after ethephon treatment), in comparison with the second tapping, were generally higher although in some treatments the responses were comparable or slightly lower.

These results generally showed that ethephon applied at positions below the cut gave better response than when applied at other sites opposite and above the tapping cut.

Effect of Repeated Stimulation on Flow Rates and Turgor Pressure of Laticiferous Tissues

Repeated stimulation of scraped bark below the tapping cut at two-monthly intervals over a period of two years results in a gradual lowering of the order of yield response with each reapplication of the stimulant[23]. Experiments were carried out to measure flow rates and turgor pressures

TABLE 1. EFFECT OF ETHEPHON APPLICATION AT VARIOUS SITES TO THE TRUNK ON THE ORDER OF YIELD RESPONSE TAPPED AT THREE-TIME INTERVALS

Site of stimulant application	Distance from tapping cut (cm)	Control Time (h) 18	42	90	Ethephon stimulation Time (h) 18	42	90
Below tapping cut	1.5	115 (100)	107 (100)	121 (100)	372 (323)	574 (536)	574 (474)
	35	159 (100)	187 (100)	188 (100)	324 (210)	606 (324)	624 (337)
	70	127 (100)	185 (100)	179 (100)	285 (224)	655 (354)	649 (363)
Opposite	1.5	136 (100)	178 (100)	196 (100)	225 (165)	413 (232)	417 (213)
	35	106 (100)	142 (100)	132 (100)	130 (123)	522 (368)	534 (405)
	70	88 (100)	146 (100)	176 (100)	147 (167)	559 (383)	571 (324)
Above	35	143 (100)	167 (100)	175 (100)	255 (178)	599 (359)	517 (295)
	70	134 (100)	170 (100)	200 (100)	125 (93)	401 (236)	395 198)

Mean yield in millilitre per tree per tapping adjusted for pre-treatment differences and expressed in parenthesis at percentage of control.

Each figure represents a mean of fifteen trees.

of RRIM 600 and RRIM 612, which had been *repeatedly stimulated for more than three* years, and the control trees. Turgor pressures were measured 2 cm to 40 cm below the tapping cut before tapping and during the first 10 min of flow.

The turgor pressure in the laticiferous vessels were markedly lower in both the stimulated clones than in the controls *(Table 2)*. Flow rates measured for the first 20 min on clone RRIM 600 indicated that they were much lower than the control *(Table 3)*. For the first 10 min the rates fell to about half that of the controls. However, due to longer duration of flow, the stimulated RRIM 600 gave higher yields than the controls.

TABLE 2. TURGOR PRESSURES BEFORE TAPPING AT VARIOUS DISTANCES BELOW TAPPING CUT ON TREES REPEATEDLY STIMULATED WITH ETHEPHON OVER THREE YEARS

Distance from tapping cut (cm)	Mean turgor pressure (atm)			
	RRIM 612		RRIM 600	
	Control	Treated	Control	Treated
2	9.72	6.73	10.19	7.36
10	9.03	7.28	10.25	8.13
20	9.39	6.54	10.26	7.73
40	9.85	8.17	9.83	9.85

Each figure represents mean of three trees.

DISCUSSION AND CONCLUSIONS

The order of response to ethephon stimulation has been shown to depend on the interval of time between application of stimulant and tapping. Incipient response to ethephon stimulation usually occurred 5 h to 6 h after application of stimulant and it steadily increased with time. A lapse of 5 h to 6 h is needed for the chemical to penetrate into the bark and initiate the necessary physiological and biochemical changes which ultimately result in prolongation of latex flow. Coupe and d'Auzac[27] recently showed that ethephon stimulation increased the concentration of ribonucleic acid and polysomes in the latex three days after ethephon treatment. However, it must be remembered that this incipient response time of 5 h to 6 h applies only for ethephon application on a 3.8 cm scraped band of bark below the tapping cut and tapped on S/2.d/2 tapping system. It is likely that other tapping systems and application sites may give different time values for incipient responses to ethephon stimulation. In this connection it is likely that ethephon applied at different times of the day will also give different incipient response values.

The results also show that the order and time of yield response to ethephon stimulation depend on the internal water balance of the tapping panel. Trees stimulated and

TABLE 3. INITIAL FLOW RATES ON CONTROL AND TREES CONTINUALLY STIMULATED WITH ETHEPHON FOR OVER THREE YEARS

Time of flow (min)	Mean flow rate (ml/min)							
	Control				Stimulated			
1	9.38	10.88	10.00	12.25	4.83	7.17	5.83	4.67
5	5.08	5.08	4.53	5.03	3.33	3.83	2.73	3.43
10	4.73	4.30	3.60	5.25	2.73	3.67	2.54	3.07
20	2.60	2.98	2.50	1.90	2.93	3.00	2.57	2.23

Clone RRIM 600

Each figure represents mean flow rate value for the three trees.

tapped early in the morning or during the night gave maximum yield responses, while those tapped during the day gave poor responses. The amount of water at the tapping panel could be one of the causes for restricting continued latex flow during the afternoon when transpiration is high. Loss of water from the panel or restriction of lateral movement of water from the xylem to the latex vessels and other bark tissues, especially during the periods of high transpiration, could impede latex flow and reduce the order of response to ethephon stimulation. This is supported by Ninane[28] who has shown that the amount of water transpired per day on twenty-year-old *Hevea* tree is 148 litres to 296 litres based on measurements taken from 0900 h to 1700 hours. Diffusion pressure deficits observed even as early as 1000 h in the laticiferous tissues near the tapping cut may be due to the development of negative pressures in the xylem as a result of transpiration.

The order of response is also influenced to some extent by ethephon application to different sites. Good yield responses were observed when ethephon was applied near or below the tapping cut. The low responses observed when ethephon was applied opposite the tapping panel and 70 cm above the tapping cut may be due partly to breakdown of ethephon before it penetrated to the site of action or possibly because of poor translocation in the lateral and downward directions.

Repeated ethephon applications severely reduced initial flow rates in RRIM 600 and 612. This reduction of flow and decrease in the turgor of the laticiferous tissues suggest a lowering of osmotic pressure or alteration of vessel elasticity and/or thickening of latex vessels. This may be due to ethylene increasing cell wall thickening[29] or inhibiting polar transport of auxin[30]. It is conceivable that continuous stimulation with ethephon may cause alteration of hormonal balance in the tapping panel which in turn might affect cell turgor pressure and flow rates.

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