BLACK THREAD DISEASE, CONTROL MEASURES AND YIELD STIMULATION IN *HEVEA BRASILIENSIS* IN LIBERIA

J. SCHREURS

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(with a summary in Dutch)

PROEFSCHRIFT

TER VERKRIJGING VAN DE GRAAD
VAN DOCTOR IN DE LANDBOUWWETENSCHAPPEN
OP GEZAG VAN DE RECTOR MAGNIFICUS, PROF. DR. IR. H. A. LENIGER,
HOOGLERAAR IN DE TECHNOLOGIE,
IN HET OPENBAAR TE VERDEDIGEN
OP WOENSDAG 22 NOVEMBER 1972 DES
NAMIDDAGS TE VIER UUR IN DE AULA VAN DE
LANDBOUWHOGESCHOOL TE WAGENINGEN

H. VEENMAN & ZONEN N.V. – WAGENINGEN – 1972

STELLINGEN

I

Het is bekend dat 'tapping towards a junction of bark of different ages leads to a severe drop in yield of the *Hevea* tree' (A. T. EDGAR; Fig. 21 in dit proefschrift). Onderzoek betreffende het optreden van 'bark islands' in herstelde bast van verschillende leeftijd is daarom dringend gewenst.

Manual of Rubber planting. The Inc. Soc. of Planters, Kuala Lumpur, p. 324 (1958).

II

De conclusie van E. F. DARLEY en S. B. SILVERBORG: 'It is evident that the (black thread) disease can be spread by the tapping knife', kan uit het door hen verrichte onderzoek niet worden getrokken.

Black thread of *Hevea brasiliensis* in Liberia. Phytopathology **42**: 547–548 (1952)

III

Ter stimulering van de latexproduktie van *Hevea brasiliensis* wordt thans in de praktijk het nieuwe middel Ethrel (actieve stof: 2-chloorethylfosfonzuur) veel gebruikt, in palmolie toegediend aan een geschraapte strook bast beneden de tapsnede. In proeven van het 'Rubber Research Institute of Malaya' (P.D. ABRAHAM) werd bij de ontwikkeling van deze methode te weinig aandacht geschonken aan lagere concentraties dan 10% actieve stof.

Field trials with Ethrel. Plrs' Bull. Rubb. Res. Inst. Malaya no 111: 366–386 (1970)

IV

Te Harbel en elders in Liberia heeft een bladziekte, veroorzaakt door de schimmel *Helminthosporium heveae*, vooral in het begin der zestiger jaren zeer veel schade aangericht in jonge *Hevea* aanplantingen. In latere jaren nam de ziekte sterk in betekenis af, hetgeen samenging met het optreden van een andere – en nauwelijks schadelijke – *Helminthosporium* soort. Het is waarschijnlijk dat er verband bestaat tussen het optreden van de ene en het verdwijnen van de andere soort.

J. SCHREURS
Wageningen, 22 november 1972

V

De in Liberia zeer algemeen op *Hevea* blad voorkomende schildluis *Pinnaspis strachani* is er waarschijnlijk de oorzaak van, dat de symptomen van Phytophthora-bladval afwijken van die op Malakka.

VI

De sterke afname in populatiedichtheid van de agaatslak (*Achatina fulica fulica*), die in 1961/'62 in een bepaald deel van Manokwari in West-Nieuw-Guinea werd waargenomen, is naar alle waarschijnlijkheid veroorzaakt door een inheemse roofvijand, een platworm van de fam. der Rhynchodemidae.

VII

De continuïteit van het onderzoek wordt in ontwikkelingslanden vaak sterk belemmerd door het betrekkelijk korte verblijf van de aldaar gestationeerde specialisten.

VIII

Het voorstel, ingediend bij het Amerikaanse Congres, om US $ 2.000.000 te voteren voor 'research and development of herbicides to destroy narcotics-producing plants without ecological effects', is irreëel.

Time, June 28, p. 16–17 (1971)

VOORWOORD

Gaarne wil ik allen danken die tot mijn vorming en het tot stand komen van dit proefschrift hebben bijgedragen.

Mijn gedachten gaan daarbij uit naar MIJN OUDERS, die zoveel gedaan hebben om hun kinderen het beste mee te geven voor hun verdere leven. In dankbare herinnering wil ik dit allereerst memoreren.

U, hooggeleerde DEKKER, en U, hooggeleerde FERWERDA, ben ik zeer erkentelijk voor Uw bereidheid als promotor op te treden. Dank zij Uw belangstelling en medewerking is het mij mogelijk gemaakt dit proefschrift te Wageningen samen te stellen. Het contact met U was steeds bizonder prettig en leerzaam. Ook het Bestuur van de Landbouwhogeschool ben ik erkentelijk voor de geboden gelegenheid.

Met U, hooggeleerde OORT, heb ik vele jaren geleden als eerste contact gezocht om te bespreken of de aard van mijn onderzoek geschikt materiaal zou kunnen opleveren voor bewerking tot een proefschrift. Mijn belangstelling voor de fytopathologie had U reeds eerder gewekt in colleges gedurende mijn studentenjaren. Als college-assistent op Uw laboratorium heb ik, mede onder leiding van de hooggeleerde KERLING, mijn kennis nog kunnen verdiepen.

I am indebted to Firestone Plantations Company for permission to publish the information I accumulated in their service in Liberia, and especially to all those on the plantation at Harbel for help and advice. Mr. J. M. ROSS, the discussions with you were always to the point. Much obliged, Murdoch, also for the pleasant co-operation under your guidance. I also wish to thank the members of the Chemical Research Department at Harbel for the tests carried out on behalf of my work. Dr. K. G. MCINDOE, Messrs G. J. KOHOUT and C. S. DINSMORE, my gratitude for interest shown, information and critical comments. JOHN KARBAH, my 'fine' and devoted assistant, thanks for carrying out and supervising the field experiments. You did a very good job!

The excellent co-operation with Chevron Chemical Company should be mentioned. Requested information was always promptly given or tests were initiated. I was very much impressed by the high quality of this research and for the generous assistance given to me in different ways.

Dr. R. L. WASTIE of the Rubber Research Institute of Malaya, I will miss in the future your thought-provoking letters on phytopathological problems in rubber.

Dr. J. A. VON ARX ben ik erkentelijk voor de verleende medewerking bij het determineren van schimmels.

Een woord van dank is ook zeker op zijn plaats aan het adres van Dr. Ir. M. A. J. VAN MONTFORT voor zijn hulp bij de wiskundige bewerking der proefresultaten, en aan Dr. G. VERHAAR, Dr. Ir. H. TEN HAVE, en vele anderen voor het aanbrengen van correcties in het manuscript. De meeste tekeningen werden door de heer R. BOEKELMAN vervaardigd. Mevrouw E. M. BROUNS-MURRAY

verzorgde het corrigeren van de Engelse tekst.
Tenslotte wil ik opmerken dat ik het contact met de medewerkers aan de Afd. Tropische Plantenteelt en de Afd. Fytopathologie zeer op prijs heb gesteld.

CONTENTS

1. INTRODUCTION

Rubber is by far the most important cash crop grown in Liberia. The first successful introduction of *Hevea brasiliensis* was made in 1906, when the Liberian Rubber Corporation established the Mt. Barclay Estate near Monrovia with seeds from the Far East. Firestone Plantations Company started a plantation at Harbel in 1926 and another unit near the boundary with the Ivory Coast in 1927 (Cavalla Plantation). Liberian citizens – and much later other foreign companies – also became interested in *Hevea* growing, and many rubber plantations were established throughout the country in later years.

In 1970, the total rubber production of Liberia was estimated at 64.7 thousand metric tons, which is 2.2% of world production. Nigerian production is of the same level, while other African countries produce considerably less. According to FAO statistics (ANON., 1970 B, p. 298), natural rubber production in 1970 compared as follows for the different rubber producing parts of the world:

	thousand metric tons
Far East	2,691
Africa	190
Latin America	30
Oceania	6
Total world production	2,917

Rubber was almost the only source of Liberian Government revenue and of exports till iron ore mining began in 1951. At present, according to HARRISON CHURCH in 1969, Liberia is African's leading exporter of iron ore and the third world producer. Whilst iron ore now accounts for some 70 per cent of exports, rubber comprises only 20 per cent.

From 1963 to 1971, I studied diseases and pests of the *Hevea* tree on the above Firestone Plantation at Harbel. With the exception of brown bast, all major diseases are caused by fungi in Liberia, as it is in other parts of the world; pests are, generally, of minor importance. The most important and widespread diseases of the *Hevea* tree in Liberia are probably black thread, root diseases (*Fomes* and *Armillaria*) and the two leaf diseases bird's eye leaf spot and Gloeosporium leaf disease (see Section 3). However, the incidence of a disease depends highly on factors such as soil, climate, clearing methods of the land before planting, planting material, age of planting, maintenance and control measures. Accordingly, other diseases than those mentioned above are often of primary importance, such as patch canker and the stem and root disease *Ustulina zonata*. Also, damage done by diseases may change with time. In Malaya, mouldy rot was a much more important tapping panel disease than black stripe in the past. However, nowadays, mouldy rot is rarely encountered; black stripe, on the other hand, is widespread and becoming more important (WASTIE, 1969). It was witnessed in Liberia that bird's eye leaf spot, the most important leaf disease in the early sixties in plantings of susceptible *Hevea* clones of 4 to 8 years of age, became gradually less damaging; by 1970, the Gloeosporium leaf disease was generally a greater problem in such plantings at Harbel.

In view of the above it is obvious that the economic importance of *Hevea* diseases is difficult to assess as the damage depends on local conditions, which also may change with time. Another problem is that the relative importance of very different types of damage must be compared, e.g. growth retardation by leaf diseases and loss of trees by root rot. Within these limits, in Liberia diseases are likely to be of less economic importance than those in many other rubber producing countries; South American leaf blight in Latin America, root rot in the Dem. Rep. of the Congo and Phytophthora leaf fall in South India are probably much greater problems than any disease in Liberia. It is of interest to add that mildew, a major leaf disease in some countries of the Far East (e.g. Ceylon), is generally of minor importance in Africa; on the other hand, *Armillaria*, one of the most damaging root rot fungi in Africa, is practically unknown as a parasite of *Hevea* in Asia.

My investigations were mainly directed towards finding better ways of control of the tapping panel disease black thread, in the Far East better known as black stripe or bark rot. Black thread was an urgent problem in susceptible *Hevea* clones as the generally used products for control of this disease failed to give sufficient protection. Accordingly, fungicides were screened in bio-assays on fungitoxic properties against *Phytophthora palmivora* – the causal agent of black thread – and the most promising chemicals further tested in field experiments. All experiments were carried out on the Firestone Plantation at Harbel. General information on the cultivation of rubber at this plantation is given in Section 2. Although the emphasis of these researches was on control measures, information was also gathered on different aspects of the disease (Section 4). After a fungicide was found which gave very promising protection against black thread, possible side effects of the treatment were studied on latex production, quality of the rubber and on bark renewal. These experiments, along with results of other tests, are described in Section 5.

It was also investigated whether the regular applications of the fungicide could be combined with above-cut stimulation of latex yield. Accordingly, salts and esters of 2,4-dichlorophenoxyacetic acid were tested in mixtures with the fungicide. Main results of these tests – also on disease control measures – were published already in previous articles (SCHREURS, 1969 and 1971). During the last 2 years of my stay in Liberia, I tested also the new latex stimulant Ethrel. Some results of this work were published by ROSS and DINSMORE (1971). Detailed information on results, obtained with yield stimulation, is given in Section 6.

2. GENERAL INFORMATION ON RUBBER CULTIVATION AT FIRESTONE PLANTATION AT HARBEL

The Harbel Plantation is located 40 km east of Monrovia along the Farmington and Du rivers. Seeds of unknown parentage from Mt. Barclay Estate were used as planting material until 1931, when the first planting of clonal rubber was made with 3 clones introduced from the East Indies in 1928. In 1931 additional clones were introduced, and since that time all new plantings at Harbel have been made either from buddings or seedlings derived from these introductions. Locally developed clones have also been planted on a considerable scale. Replanting of the first low-producing seedling areas started in 1951, and by 1964 most of these areas had been replanted with high-producing rubber. The Harbel Plantation is the largest continuous rubber plantation unit in the world with 25,000 hectares of rubber in tap and 7,000 hectares of immature rubber. Over the years 1968 to 1970, the total yearly production of the two Firestone plantations in Liberia amounted to 37 thousand metric tons.

Details on the introduction of the *Hevea* tree to Liberia and on the development of the Harbel Plantation were given by McIndoe (1968). Harrison Church (1969) described the more general aspects of the Firestone plantations and other foreign enterprises in Liberia.

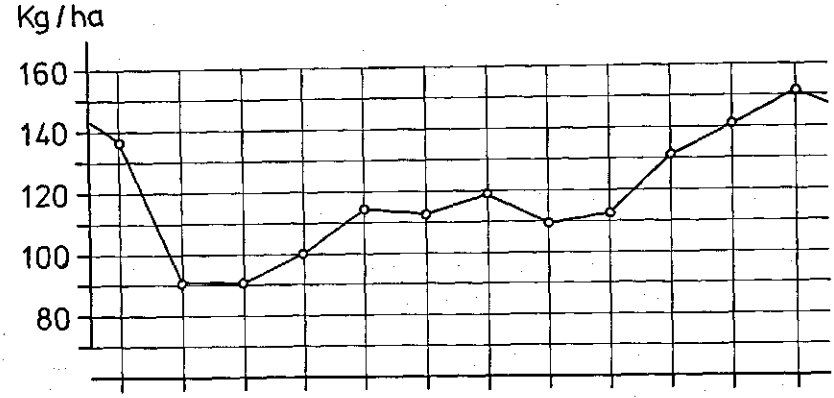
Climate and soil

The annual rainfall amounts to 3241 mm, the average of 34 years in the Botanical Research area of the plantation. The lowest annual rainfall was 2320 mm and the highest 4313 mm. There are two distinct seasons, the dry season from November to April and the rainy season from May to October. The driest month is January with 37 mm of rain on the average and the wettest month is September with 596 mm. Further data on rainfall and also on sunshine, temperature and relative humidity are given in Fig. 1. Mean figures for the period 1964–1970 are added because most field experiments were carried out during these years.

Distribution of rainfall over the different months of the year at Harbel has much in common with the rainfall pattern in South India. In Malaya, Ceylon, Java and Sumatra, rainfall is in general more evenly distributed and occurs less often in the morning when compared with the situation at Harbel. The annual rainfall in the above mentioned countries varies between 2,500 and 4,000 mm in the rubber growing districts.

The land is of a gently rolling nature with few hills and flats. There are numerous small and larger swamps over the entire plantation, amounting roughly to 30% of the total area. The swamps are left as they are or are used for growing rice and other annual crops.

Most soils are red or yellow coloured and contain a high percentage of alumi-



	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
Monthly rainfall in mm													*total*
1936–'70	37	57	127	167	279	407	444	488	596	379	185	75	3241
1964–'70	41	38	87	195	295	399	374	589	477	355	171	63	3084
Mean daily hours of bright sunshine													*mean*
1936–'70:	5.4	5.5	5.4	5.0	4.5	3.2	2.0	1.5	2.2	4.1	4.9	4.8	4.0
1964–'70:	5.5	6.0	5.9	5.2	5.0	3.6	2.3	1.6	2.4	3.8	4.6	4.4	4.2
Mean daily maximum temperature in °C													*mean*
1936–'70:	31.3	32.3	32.4	31.9	30.9	29.0	27.2	26.8	27.9	29.5	30.3	30.5	30.0
1964–'70:	31.2	32.4	32.8	31.9	30.8	28.7	26.8	26.4	27.6	28.8	29.8	30.1	29.8
Mean daily minimum temperature in °C													*mean*
1936–'70:	20.7	21.3	21.6	21.8	21.9	21.7	21.2	21.2	21.6	21.7	21.5	20.9	21.4
1964–'70:	20.9	21.5	22.2	22.6	22.5	22.1	21.4	21.6	21.6	21.9	21.8	21.4	21.8
Mean relative humidity for 1964–'70													*mean*
9:00	90	82	82	84	87	90	90	91	89	87	87	91	88
13:00	57	54	56	66	72	81	83	86	83	79	72	69	72

FIG. 1. Mean dry rubber production per month for 24,500 ha mature rubber at Harbel during 1964 to 1970. The meteorological data refer to 2 periods, viz. 1936–'70 and 1964–'70.

nium. These heavily weathered soils are generally quick draining and contain low reserves of the major nutrients. It is therefore not surprising that on these infertile soils very satisfactory responses to fertilizers are obtained.

Planting material

The *Hevea* clones most extensively planted in the thirties and forties were AVROS 49, 50 and 152; Tjir 1 and 16; BD 5 and 10; War 4; PB 180, 183 and 186. Since the early fifties the locally developed clone Har 1 (derived from 'Harbel') was planted on a large scale and more recently GT 1, PR 107, RRIM 600 and the locally developed clone Har 43.

The reported field experiments for black thread control and yield stimulation were – with a few exceptions – carried out in BD 5 plantings because this clone is very susceptible to the disease, responds well to stimulation and has been planted on a very large scale (4,000 hectares in production in 1969).

Replanting

At Harbel new land is no longer developed. The new plantings are replacements of low yielding old plantings. In the earlier days the trees were cut down by manpower and stumps were left in the soil without any treatment. In several replantings root rot became a major problem as the unpoisoned stumps were sources of infection of root rot fungi. In general, root rot incidence is much lower in the newer replantings which were established on mechanically cleared areas or in areas where the old rubber stand was poisoned with 2,4,5-trichlorophenoxyacetic acid (2,4,5-T). Mechanical clearing is done with caterpillar tractors, equipped with stumper and tree-dozer attachment.

Since the mid-fifties the avenue planting system has been mainly used for replanted areas (planting distances are approximately 9 × 3 m). Standard planting density for clonal rubber is 150 trees per acre (370 to the hectare). The older plantings were generally planted on a square system with distances of approximately 4 × 4 m.

Tapping

Young rubber stands are taken into tapping when at least 60% of the trees have a diameter of 15 cm or more at 1.50 m above ground level, which is generally about 6 years after planting with regular fertilization. In Ceylon, clonal plantings are brought into tapping when 70% of the trees have obtained a girth of 20 inches at a height of 3 feet, thus when slightly thicker (DE SILVA, 1961). The first opening in clonal rubber at Harbel is at a height of approximately 1.70 m from the ground to the lowest point of the tapping cut. Task sizes are between 400–475 trees in older rubber and 500–600 in young plantings.

Rubber trees are usually tapped for half the number of days of the year. Accordingly, each planting (or another unit) is divided in 2 sections, in Liberia named the A farm and the B farm. One farm will rest when the other is being tapped. Alternate daily tapping on half-circumference, equivalent to an average of a quarter cut tapped daily, is taken as standard (100%) in estimating relative intensity (EDGAR, 1958, p. 326). At Harbel, the standard tapping system is half spiral cuts at 100% intensity. The trees are tapped on alternate days (also called 'alternate daily tapping') or are tapped daily for a number of days and then allowed to rest for the same number of days (daily periodic tapping). The alternate daily tapping system is denoted: S/2.d/2.100% (half spiral cut, 1 day tapping out of 2 days, 100% intensity). When trees are on the daily periodic tapping system, they are tapped daily for 10, 15, 23 or 30 days (or 1 month) at Harbel, which system is denoted, e.g. for 15 days periods: S/2.d/1.15d/30.100% (half spiral cut, daily tapping, 15 days tapping out of 30 days, 100% intensity); when tapping is daily for a whole month, the system is briefly referred to as "monthly periodic tapping" (S/2.d/1.m/2.100%). Different tapping systems are used in old plantings to obtain maximum yields during the last years before replanting (V-cuts on high panel). For more information on tapping systems see EDGAR (1958, p. 325–337).

The normal rate of bark consumption is 1.6 mm per tapping cut, measured in vertical direction, and amounts to approximately 30 cm consumed bark each year. This allows for 5 years tapping on one side of the stem, after which the panel is changed to the other side on half spiral tapping at 100% intensity. In practice, however, panels often have to be changed sooner because tappers tend to over-consume bark; also, an allowance has to be made for the height of the union from the ground.

Stimulation

Stimulants are used to increase latex yield. In practice, stimulants are not applied during the first tapping cycle and at the earliest when tapping is on first bark renewal. 2,4-D is widely used for this purpose in Liberia and recently the new stimulant Ethrel has also been used. The stimulant is applied either immediately above the tapping cut or on a scraped band of bark immediately below the cut. For above-cut stimulation the butyl ester of 2,4-D is applied in the petrolatum Treseal (0.25–0.50% acid equivalent of 2,4-D) and for below-cut stimulation in palm oil (generally in 1% acid equivalent). Generally, applications are made weekly in above-cut stimulation; in below-cut stimulation the next application is not made until the treated bark (usually a band of 7.5 cm wide) is tapped off. Stimulation with 2,4-D above the cut is mainly done in older rubber during the last tapping cycle since bark treated in this way becomes greatly proliferated; another reason is that the renewed bark is often too thin and too irregular to allow for scraping below the cut. Younger trees are usually stimulated below the cut as bark renewal is practically normal.

Production

In 1970 the average production of the Harbel Plantation was close to 1,500 kg dry rubber per hectare per year. Variation in yield during the different months of the year is shown in Fig. 1. Production is lowest during the dry months of February/March when trees are wintering and refoliating.

THOMAS (1970) collected data on the production curve of plantings over a 25-year period in Malaya. On the average, highest yields per hectare were harvested in the ninth year of tapping, after which production maintained a high level during several years and then gradually decreased; in the 25th year of tapping yields had dropped to about 75% of the yield of the three most productive years.

3. REVIEW OF DISEASES, PESTS AND OTHER CAUSES OF DAMAGE IN HEVEA IN LIBERIA

A report is given on the fungi, insects, mites, mammals and mistletoes, known to cause primary damage in Liberia. Kind of damage and importance are briefly described, also non-parasitic abnormalities. Brief information is also given on control measures for the most important causes of damage. The data were collected at Harbel and on the neighbouring Mt. Barclay Estate.

3.1. FUNGI

The fungi were identified (or identifications that had been made previously were checked) by the Centraalbureau voor Schimmelcultures at Baarn, the Netherlands, except for *Corticium*, *Fomes* and *Ustulina*. It is recorded by whom and when the disease was first reported. These records were found in unpublished reports of the Botanical Research Dept. of Firestone Plantations Co.

Aleurodiscus sp.: SCHREURS, 1969. Root and collar rot; one record only.
Armillaria fuscipes PETCH: SCHREURS, 1964. A major root disease.
Botryodiplodia theobromae PAT.: MCINDOE, 1931. Possible cause of certain die-back symptoms.
Colletotrichum gloeosporioides PENZIG: SCHREURS, 1963. The ascigerous state is named: *Glomerella cingulata* (STONEM.) SPAULD and SCHRENK. The common name for this important leaf disease is Gloeosporium leaf disease. STAKMAN identified a *Gloeosporium* sp. in 1930, probably the same fungus as mentioned above.
Corticium salmonicolor BERK. and BR.: STAKMAN, 1930. Pink disease is a rather severe problem in the few susceptible *Hevea* clones planted at Harbel. The fungus affects bark of stem and branches, particularly at the fork.
Ganoderma sp.: STAKMAN, 1930. Probably the cause of red root rot and, generally, of minor importance.
Helminthosporium sp.: SCHREURS, 1964. This fungus, different from *H. heveae*, was very wide-spread in 1964 and caused many tiny leaf spots without doing visible damage.
Helminthosporium heveae PETCH: STAKMAN, 1930. Bird's eye leaf spot is a major leaf disease in Liberia.
Oidium heveae STEIN.: SCHREURS, 1965. Damage done by mildew was seen only occasionally.
Phellinus noxius (CORNER) CUNNINGHAM: STAKMAN, 1930. Brown root rot is locally a major root disease. STAKMAN identified the fungus under its old name: *Fomes noxius* CORNER.

Phytophthora palmivora (BUTLER) BUTLER 'rubber group': STAKMAN, 1930. Black thread is a major disease, attacking the tapping panel. TAPPAN (1960) identified the same fungus as causal agent of Phytophthora leaf fall, occasionally causing extensive leaf fall in susceptible *Hevea* clones.

Pythium vexans de BARY: DARLEY, 1945. Patch canker is an important disease in susceptible *Hevea* clones, causing rotting of bark on roots, root collar and stem.

Rigidoporus lignosus (KLOTZSCH) IMAZEKI: STAKMAN, 1930. White root rot is a wide-spread and major root disease in Liberia. STAKMAN identified the fungus under its old name: *Fomes lignosus* (KLOTZSCH) BRES.

Sphaerostilbe repens (BERK. and BR.) PETCH: STAKMAN, 1930. Stinking root rot is probably of minor importance.

Ustulina zonata (LÉV.) SACC.: STAKMAN, 1930. This stem and root disease causes rather important damage in older *Hevea* plantings.

The following fungi are of minor importance or of secondary nature; they were isolated from *Hevea* trees since 1963.

From leaves: *Aspergillus japonicus* SAITÔ; *Curvularia pallescens* BOEDIJN; *Diaporthe heveae* PETCH; *Didymosphaeria winteri* NIESSL; *Fusarium javanicum* KOORD.; *F. semitectum* BERK. and RAV.; *Pestalotia palmarum* COOKE; *Phyllostictina theicola* (SIEM.) PETR.

From stem and branches: *Bispora pusilla* SACC.; *Choanephora cucurbitarum* (BERK. and RAV.) THAXTER; *Colletotrichum crassipes* (SPEG.) v. ARX; *Fusarium javanicum* KOORD.

In practice, the following fungal diseases are regularly controlled at Harbel Plantation:

Black thread: Applications of captafol are made weekly from May through December in all plantings in tapping, except for those stimulated above the cut with stimulant in petrolatum.

Root rot: This group of diseases does most damage to immature rubber and to rubber in its first years of maturity. Main sources of infection are old stumps and diseased roots of neighbouring trees. Control measures consist of elimination (up-rooting and burning) and isolation (trenching) of sources of infection to prevent further spread of the disease. When a minor part of the root system is found to be affected, diseased parts are cut off and burned and cut surfaces are sealed off with coal tar. During the most susceptible period (in plantings of 3 up to 10 years of age) all trees are inspected several times a year.

Patch canker: The symptoms are very similar to those described by O'CONNOR (1969) and RAMAKRISHNAN (1963). According to O'CONNOR (1969) the disease may be caused by *Phytophthora palmivora* or *Pythium complectens*. In Liberia, only *Pythium vexans* (synonymous name: *P. complectens*) was isolated from typical patch canker wounds, which are often elliptically shaped. The first signs are vertical cracks in the bark, and foul-smelling rubber is found underneath in the cambial layer, separating wood and diseased bark. Infections of taproot, large lateral roots and union are most damaging on trees of 4–8 years of age in Liberia. The disease seldom kills trees but certainly retards growth. With older trees, patches may occur anywhere on the stem. A satisfactory preventive or curative method of control has not yet been found. Diseased bark is excised and the wound treated with a fungicide and sealed off with petrolatum.

Bird's eye leaf spot: Nurseries and budwood gardens are sprayed weekly from December through April with 1.1 kg Daconil 75% wettable powder per hectare; the active ingredient is tetrachloroisophthalonitrile. This fungicide was found to be outstandingly effective against this disease.

3.2. Insects and mites

The following insects and mites have been collected on *Hevea* trees since 1963 and identified by the Commonwealth Institute of Entomology at London, England.

Insects:	fam. Coccidae:	*Saissetia niger* (NIETNER)
	fam. Diaspididae:	*Lepidosaphes* sp.
		Pinnaspis strachani (COOLEY)
	fam. Pseudococcidae:	*Ferrisia virgata* (CKLL.)
	fam. Scolytidae:	*Platypus hintzi* SCHAUF.
		Xyleborus affinis EICHH.
		Xyleborus alluaudi SCHAUF.
Mites:	fam. Tarsonemidae:	*Hemitarsonemus latus* (BANKS)
	fam. Tetranychidae:	*Eutetranychus clastus* BAKER and PRITCHARD

Pinnaspis is a very common insect on mature *Hevea* leaves and thin branches, probably not doing much damage. Coccidae and Pseudococcidae cause occasional damage in nurseries, budwood gardens and in young plantings. Scolytidae attack weakened or dying trees; they invade bark and wood in large numbers in such instances. The yellow mite (*Hemitarsonemus*) often causes severe defoliation in nurseries and budwood gardens. Although this pest can be controlled very effectively with endrin (2 sprayings with an interval of 10 days), this product is no longer used because of its high toxicity to human beings. The spider mite *Eutetranychus* was observed once only as a pest in nurseries. STAKMAN reported in 1930 that the longicorn beetle *Batocera rubus* attacked *Hevea* trees; the larvae bored in taproot and lower part of the stem.

3.3. Physiological diseases

Brown bast belongs to the major rubber diseases in Liberia and other parts of the world. This physiological disorder causes dryness (latex production ceases) and severe burring of the trunk. SPANGLER and MCINDOE (1949) distinguished 'dry' trees and 'chronic' cases in Liberia. Dry trees are those whose tapping cuts are dry for unknown reasons, or on account of early manifestation of the disease. Chronic cases are those on which the panels become marred by the burls and irregularities typical of advanced stages of the disease. CHUA (1967) reported that the incidence of dryness becomes greater when the tapping intensity is increased. The frequency of tapping plays a more important role than the length of cut in inducing dryness, but the combination of both, increased frequency and lengthening of the cut, results in a very severe incidence of dryness. Accordingly, when the incidence becomes serious, the tapping intensity should be reduced. Some clones are more liable to brown bast than others and clonal seedlings more than most clones. An incidence of 10–20% dry trees is not infrequently encountered in susceptible plantings in Liberia.

3.4. OTHER CAUSES OF DAMAGE

Rats and groundhogs sometimes do considerable damage in newly planted areas. A *Loranthus* sp., belonging to the mistletoes, is sometimes a problem in some places. Occasionally damage is done by storms, lightning, drought, waterlogging and fire. Wind damage is most important and causes each year considerable damage in susceptible plantings. Some clones are more liable to breakage than others. Sanitation measures are taken to prevent the broken trees from becoming sources of infection of root rot. Accordingly, when trunk snap occurs above the highest point of the tapping panel, the stem is cut back into the undamaged part and the cut surface is sealed off with a protective coating. Trees which break at a lower level are poisoned.

4. BLACK THREAD DISEASE

4.1. SYMPTOMS AND DAMAGE

4.1.1. *General information*

DARLEY and SILVERBORG (1952) described many different aspects of the black thread disease in Liberia. Further information on this disease was given by myself in a previous article (SCHREURS, 1969). The main points are reviewed below.

Black thread, also known as black stripe or bark rot, is common in most of the rubber growing regions of the world and is in many countries a real problem. In Liberia, it is often the most damaging disease in plantings of above average susceptibility when adequate control measures are not taken.

The renewing bark of the recently tapped portion of the panel is subject to infection during the rainy season. According to DARLEY and SILVERBORG (1952) the renewing bark becomes resistant to infection within 4 to 6 days after tapping; after 8 days the bark is immune. STEINMANN (1925, p. 42) mentioned, however, that the renewing bark up to 5 cm above the cut is still subject to infection. SATCHUTHANANTHAVALE (1971) reported that the corky layer of the bark is resistant to infection, but that all other tissues below this layer are penetrated by the fungus. The soft bast is more susceptible than the outer hard bast.

The first external signs of attack are short, vertical linear, shallow depressions above the cut. In severe cases there are many affected patches which may coalesce laterally, resulting in a continuous wound which extends right across the tapping cut. The wood underneath the affected bark contains narrow black lines which give the disease its name. The diseased bark deteriorates, the cambium is killed and, eventually, the wood is exposed. In Fig. 2 a tapping panel is shown that was severely affected during 3 consecutive rainy seasons; it is remarkable that the wounds are similar in shape. Sometimes the lesions enlarge rapidly, also below the tapping cut, and a large part of the tapping panel may be ruined. The necrotic bark below the cut can be attacked by pinhole borers, also observed in Malaya (ANON., 1970 A). It is mentioned in this Malayan article that pads of latex are sometimes formed beneath the bark, resulting in extensive bark splitting and bleeding. When such symptoms were seen in Liberia, they were the result of secondary infections with patch canker.

Generally, the wounds start healing with the onset of the dry season. Healed wounds have irregular bark, which is difficult to tap and is possibly of lower production level. WASTIE and CHEE (1969) summarized the noxious effects of black thread as follows: 'The disease prevents the healthy regeneration of tapped bark leaving, at best, an uneven surface unsuitable for re-tapping and, at worst, large wounds which expose the wood, rendering subsequent tapping impossible'.

4.1.2. *Healing process of black thread wounds*

Abnormal bark renewal occurs on tapped bark when the cambium is damaged

FIG. 2. The tapping panel of this 25-year-old BD 5 tree was severely affected by black thread during 3 consecutive rainy seasons. It is remarkable that the wounds are similar in shape. The photograph was taken at the beginning of the dry season. The scale is 1:10.

(e.g. black thread or too deep tapping). In such cases there is also some die-back in the outer layers of the wood. In the case of black thread, the black stripes may be found 12 mm deep in the wood (SHARPLES, 1936). Such wounds can only be healed by the growth of new wood and bark arising from the cambium at its edges. Where wounds have healed the stem is swollen up because of the abnormal cambium activity.

In Fig. 3 – reproduced from a previous article (SCHREURS, 1969) – a severe case of black thread damage and how the wounds are healing is shown. These observations were made on a BD 5 tree, which was 19 years old when the pictured damage was done.

For estimating the progress of healing tissue, the width of the exposed wood was measured on a number of wounds at different times. The observations were made in a 1945 BD 5 planting, tapped on first bark renewal. The black thread wounds had developed during the months of August and September 1964.

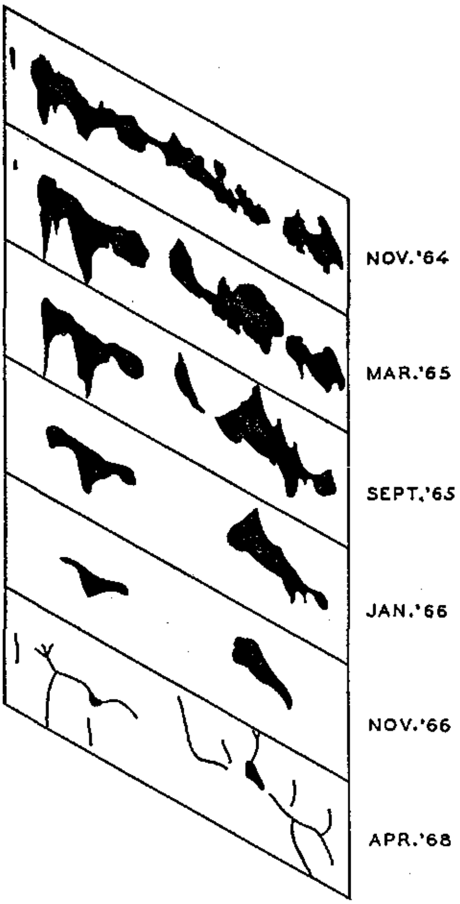


FIG. 3. Appearance of same black thread wounds from Nov. 1964 to Apr. 1968. The blackened areas represent completely dead bark; the scale is 1:10.
Nov. '64: situation 2–3 months after infection.
Mar. and Sep. '65: some wounds are healing, others extending (the disease has spread or already diseased bark has died).
Jan. and Nov. '66: all wounds are healing.
Apr. '68: the wounds have almost healed. Note the scars.

Measurements were taken of wounds on untreated panels and on panels which had been regularly treated with Treseal for black thread control. In Table 1 the progress of healing tissue on the edge of wounds is given in mm per month, mean figures of measurements made on 10 trees per treatment. Because healing is from all sides, wounds heal twice as fast as indicated in the table.

TABLE 1. Progress of healing tissue in black thread wounds in mm per month during different periods.

Treatments	Nov '64– Jan '65	Jan '65– Mar '65	Mar '65– Sep '65	Sep '65– Jan '66
Untreated panels	0.26	0.13	0.78	0.96
Treseal treated panels	1.22	0.69	0.93	1.00

The figures show that:

a. the wounds on the untreated panels healed very slowly during the first months of observation as the disease was still active in many cases and healing had not yet started.

b. healing was faster on Treseal treated panels. It may be a coincidence that this was so right from the beginning as the fungus can still be active towards the end of the rainy season in such wounds.

c. in all cases healing was slowest during the driest months (January/February).

d. normal progress of wound tissue was roughly between 0.75 and 1 mm per month, so wounds became 1.5–2.0 mm narrower.

Data on healing of artificially made wounds are given in Section 6.3.5.2.

4.1.3. *Appearance of old black thread damage inside Hevea stems*

The stems of some 25-year-old BD 5 trees with a severe black thread history were sliced up into cross sections of about 25 mm thick to study the effect of old infections on wood and bark formation. For the same purpose some other trees were cut lengthwise in two halves.

The tapping history of these trees was as follows. Trees were brought into tapping in 1952. Tapping was on north panel from 1952 to 1956, on south panel from 1956 to 1960, on north panel from 1960 to 1964, on south panel from 1964 to 1968, and again on north panel since 1968.

The section shown in Fig. 4 is from the lower half of a stem, which was tapped twice on either panel when the tree was cut down in February 1971. The old black thread infections left clear marks in the wood; the necrotic tissue was dark brown to black in colour. On the north/east side of the section, the wood – produced after 1955 – was greatly proliferated because healing and rotting occurred several times. Although tapping wounds might have contributed to abnormal wood formation, the main cause of damage was black thread as the swellings of the stem were on the portions tapped during the rainy seasons and followed the direction of the tapping cut; tapping wounds are not bound to a certain time of the year. The swellings are very clearly visible in Fig. 5. BEELEY observed these typical swellings already in 1929: 'In districts where black stripe is of frequent occurrence several rows of such healing wounds may be observed on the panel, each row corresponding to that part of the panel which was tapped during the wet months of the year, i.e. at a time when the disease was active'.

Remarkable are the black lines in radial direction, which often continued in the wood formed after the next tapping cycle. Such connections are not clearly visible in Fig. 4 because the lines do not follow an entirely horizontal level (Fig. 5). These symptoms have much in common with those described by STEINMANN (1925) for healed tapping wounds. The necrotic tissue in these radial lines probably consists of cork mainly as healing tissues have met there, resulting in enclosures of cork in the newly formed wood. The exterior of the stem shows a knob in front of a black line because wound wood is produced in greater amounts than normal wood. The bark on top of knobs is thin. Attempts to isolate *Phytophthora* from different necrotic tissues in the wood failed.

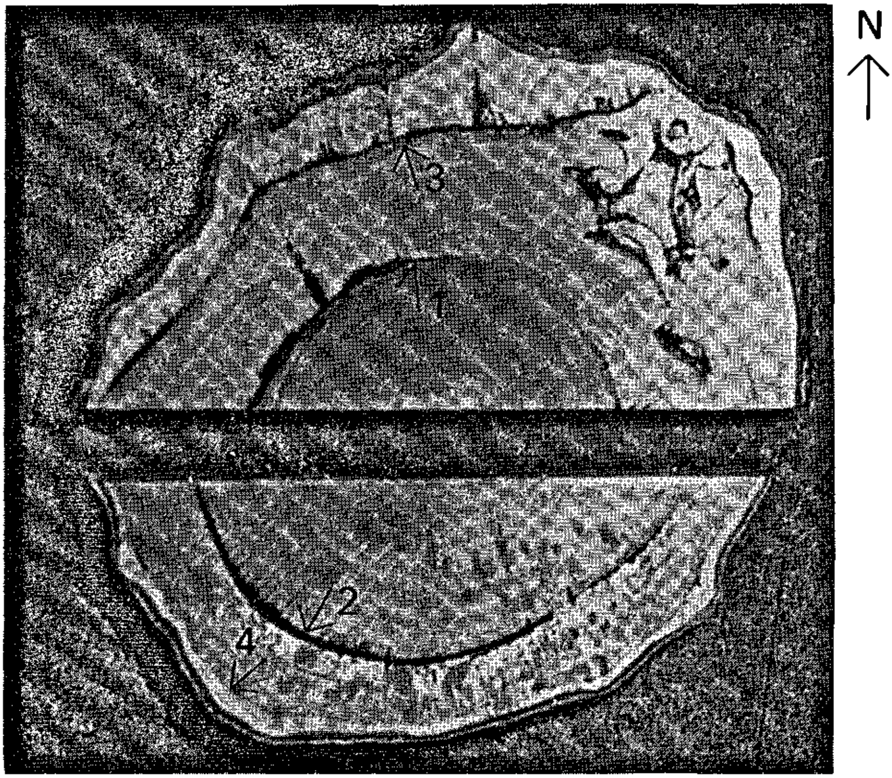


FIG. 4. Cross section through 25-year-old BD 5 stem with severe black thread history. The scale is 1:3. At this height of the stem, tapping was on the north panel in 1955 (1) and 1963 (3), and on the south panel in 1959 (2) and 1967 (4). The north side of the section was due to be tapped for the third time. Note that wood formation is slowed down when trees advance in age; compare thickness of wood between 1 and 3, 2 and 4, and between 3 and exterior.

It is evident that severe black thread infections, even when wounds have healed, have several markedly adverse effects on the tree. Bark renewal is irregular, resulting in loss of crop (latex flow over the edge of the tapping cut; bark possibly of lower yield potential) and more tapping wounds during the next tapping cycle. Such ill effects are extremely damaging as – to quote PETCH (1911, p. 75) – 'the duration of a rubber plantation under normal conditions depends upon the character of the renewed bark.' Such trees are also more susceptible to trunk snap.

In Section 4.2.4. it is shown that a close positive correlation exists between the occurrence of new and old black thread wounds, observed in young plantings (still tapped on virgin bark) and on older trees (tapped on renewed bark). It is possible that in the latter case the greater susceptibility is connected with the irregular bark renewal, as more tapping wounds are made, which might increase infection chances.

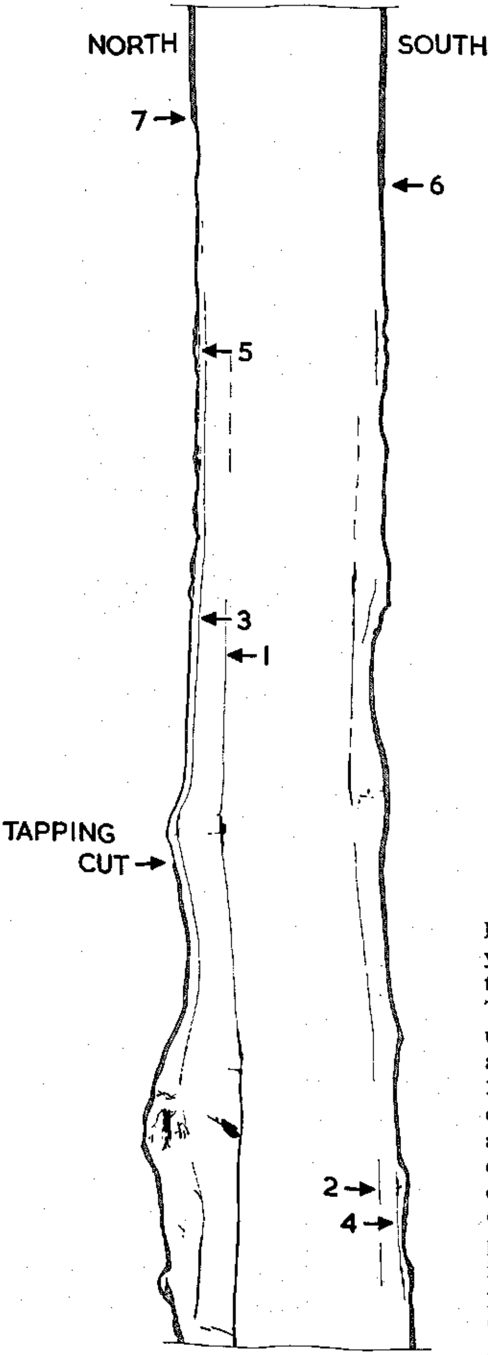


FIG. 5. Longitudinal section through 25-year-old BD 5 stem with severe black thread history. The scale is 1:10.
The stem was cut 10–20 cm above the union. The numbered vertical, thin lines are marks of the different tapping cycles (1, 3 and 5 are from the first, second and third cycle on north panel; 2 and 4 form the first and second cycle on south panel). The thicker parts of these vertical lines represent necrotic wood, mainly caused by black thread. Other blackened parts in the wood are probably mainly cork enclosures or necrotic wood. The highest points of the 2 tapping panels are indicated with the figures 6 (panel change in 1964) and 7 (panel change in 1968); above these levels is virgin bark.

4.1.4. *Evaluation criteria*

In field experiments the degree of wounding by black thread was estimated usually at the end of the rainy season, using the following standard of evaluation (SCHREURS, 1969):

	Approximate % of dead bark up to
0 = healthy panel	0
1 = one or some not very distinct infections	1
2 = a few typical black thread infections	2½
3 = several to many deep, vertical depressions	6
4 = as under 3, but diseased parts coalesced	15
5 = large patches of new bark dead	50
6 = most of new bark dead	100

This evaluation system gives a quite accurate account of the degree of wounding by black thread. When such observations were repeated on the same trees within a few days or weeks, practically the same estimated values were obtained. In some field experiments results of different treatments were evaluated twice, once at the end of the rainy season and once more several to six months later. In these instances the relative differences between mean damage figures remained practically the same (see exps 21 and 35 in Appendix). In Exp. 21 the evaluations of March 1968 were all of a lower level when compared with the figures collected in November 1967 because wounds had healed since. In Exp. 35 much more damage was done and the situation had not changed much six months later (compare December 1969 with June 1970 evaluations).

4.1.5. *Incidental infections of the tapping panel by Phytophthora palmivora*

When rubber trees are taken into tapping for the first time – or when the tapping panel is changed to the other side of the tree – at first a not very deep incision (not reaching the latex vessels) is made to mark where tapping should commence. This 'panel mark' is placed several weeks or months before tapping starts. In the unusual case under review this was done even a whole year in advance. The panel marks became severely affected by black thread. This happened in a 25-year-old BD 5 planting. The new panels were laid during the rainy season and panels were marked too deeply as coagulated latex was found in these cuts later on.

Under these conditions many panel marks became infected by *Phytophthora palmivora*. A large part of the bark had died in the panel marked area of the tree shown in Fig. 7 and wood became exposed. The wound was bordered by healing tissue and adventitious roots had formed when this photograph was taken, about a year after the new panel was laid. A similar case is shown in Fig. 6; the sunken bark is dead and has not yet sloughed off.

Such infections are also known from other countries, e.g. Malaya (ANON., 1970 A) and it is recommended 'not to open trees for tapping, or change the panel, during wet weather in areas where black stripe is liable to be severe'. It

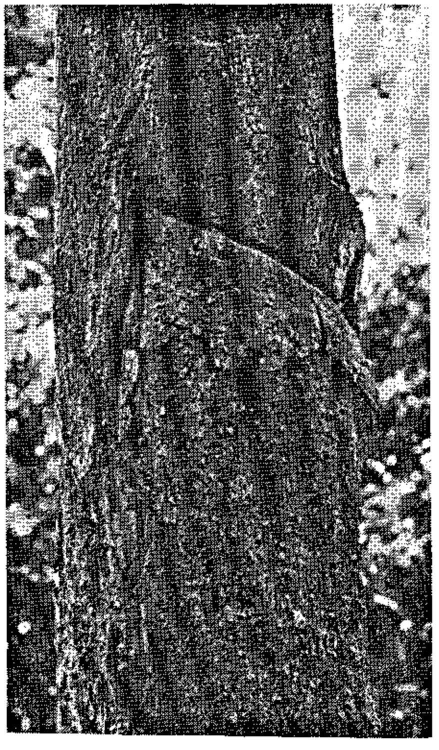


FIG. 6. Panel mark damaged by black thread. The dead bark has not yet sloughed off. The scale is 1:7.

FIG. 7. Panel mark damaged by black thread. The dead bark has sloughed off. The wood in the wound is exposed and is bordered by healing tissues. Note the adventitious roots. The scale is 1:7.

should be possible, however, to prevent infections of newly opened panels – also during the rainy season – with timely application of a suitable fungicide.

4.2. CAUSAL AGENT, SOURCES OF INFECTION, DISSEMINATION AND PREDISPOSING FACTORS

4.2.1. *General information*

Phytophthora palmivora (BUTLER) BUTLER is generally accepted as the causal agent of black thread. However, PERIES (1966 A) is of the opinion that bark rot (= black thread), die-back of shoots, pod rot and secondary leaf fall of *Hevea* in Ceylon is caused by *P. meadii* MCRAE. According to CHEE (1969 A) the disease can also be caused by *P. botryosa* sp. nov. in certain parts of Malaya. DARLEY and SILVERBORG (1952) found that there are at least 2 strains of *P. palmivora* in

Liberia, 'form 2' being more virulent than 'form 1'. *P. palmivora* has many host plants; CHEE (1969 B) compiled a list of 138 plant species. Although different groups of *P. palmivora* are distinguishable, e.g. 'rubber' and 'cacao' groups, isolates from cacao may readily infect rubber pods (TURNER, 1961). The fungus can infect pods, leaves, shoots and tapping panel of *Hevea brasiliensis*.

The fungus produces sporangia, chlamydospores and cospores. WATERHOUSE (1963) gives the following data on the species *P. palmivora:* 'sporangia of various shapes, but many elongated ellipsoid or elongated ovoid, mostly 50–60 × 31–35 (max. 93 × 43) μ. Chlamydospores up to 55 μ, and mostly 30–35 μ. Oospores on the average 30 (max. 42) μ'. According to DARLEY and SILVERBORG (1952) the average size of sporangia in Liberia for 'form 1' was 51.5 × 33.9 μ and for 'form 2' was 33.1 × 26.2 μ.

The disease spreads by means of sporangia. A sporangium releases up to 26 zoospores (7–11 μ) or may germinate as a conidium. According to STEINMANN (1925, p. 40–41) during the rainy season the disease is mainly spread by the zoospores. Chlamydospores are usually formed within diseased tissues (REYDON, 1931) and germinate within 24 hours in water (STEINMANN, 1925, p. 40). CHEE (1969 C) mentions that oospores have been found in large numbers in rotten, shriveled and malformed pods. On culture media, oospores are only formed in mixed cultures of isolates (TURNER, 1961). Because they are difficult to germinate, their function is largely unknown (ANON., 1967).

Infections of the tapping panel originate probably from the following sources:

a. *Hevea* pods and leaves, and from volunteer rubber seedlings (REYDON, 1931). Each year, the green pods are affected first and then the leaves (India: RAMAKRISHNAN and RADHAKRISHNA, 1961; Ceylon: PERIES, 1969; Malaya: CHEE, 1969 C). However, Phytophthora leaf fall has been seen in the virtual absence of pods (CHEE, 1969 C). The importance of diseased pods and leaves as sources of infection to the tapping panel depends probably on local conditions. In Liberia, the *Hevea* clone BD 5 is very susceptible to black thread, although Phytophthora leaf fall is rarely encountered in such plantings; to what extent the pods are affected was not investigated. DARLEY and SILVERBORG (1952) isolated *Phytophthora palmivora* also from dead twigs in Liberia.

b. Affected tapping panels of neighbouring trees (REYDON, 1931). There is no evidence that infections originate from old lesions on the stem (ANON., 1970 A). However, DARLEY and SILVERBORG (1952) came to the conclusion that older black thread wounds may be a site in which the fungus lives over dry periods as the fungus was isolated once from each of 3 wounds, 1, 2 and 3 years old.

c. Other host plants of *P. palmivora* (see list of hosts, given by CHEE, 1969 B). It was observed that the incidence of black stripe is frequently higher near worker's living quarters, perhaps because alternate hosts of *P. palmivora*, commonly planted in such areas, increase spore population (ANON., 1970 A).

d. The soil. PERIES (1966 B) reported that the fungus can spread from the soil, because it can grow in the soil as long as there is sufficient organic matter in it; from the soil the fungus can be splashed on to the tapping panel during heavy rains. However, more recently it was discovered that the fungus is present in the soil only at the time of occurrence of black stripe or leaf fall and therefore little importance should be attached to the soil as a reservoir of the pathogen.

The above facts and theories suggest that the importance of the different possible sources of infection probably depends highly on local conditions.

Phytophthora probably disseminates by both windborne and rainborne spores (ANON., 1970 A). PERIES (1969) is of the opinion that Phytophthora leaf disease is spread about almost exclusively by rain splash, wind having little effect, as dessiccation rapidly kills sporangia and zoospores. It is questionable whether PERIES' theory is also valid for infections of the tapping panel; windborne spores are possibly given a better chance to survive on this part of the tree than in the canopies, in view of differences in microclimate.

There are many factors affecting susceptibility of the tapping panel to black thread, e.g. (ANON., 1970 A):

a. Climate. Black thread infections occur during prolonged periods of cool, wet weather with constant high humidity and little sunshine. Dry weather quickly arrests the disease and a callus is formed around the edges of the wounds (BEELEY, 1929).

Accordingly, in Liberia, with a distinct dry and wet season, infections occur mainly during the wet and relatively dark and cool months of July through October. Optimum conditions for black thread infections are probably prolonged periods of light rainfall (inoculum is washed down to the tapping cut and can remain there to initiate infection), rather than heavy rain (inoculum is washed off the tapping panel) (PERIES, 1965). The optimum range of temperature is 21–27°C (ANON., 1961). The observation of PILAAR (1935) and VAN SCHOONNEVELDT (1950) that black thread is often more severe at higher altitudes is possibly connected with lower temperatures at higher levels.

b. Topography, spacing of trees and thickness of canopies. In low-lying areas around swamps, in close plantings and when the trees have dense canopies, the microclimate around the tapping panel is rather damp and dark, favouring the spread of the disease. BEELEY (1929) mentioned that luxuriant cover crop around the base of the tree also tends to increase humidity and, therefore, should be avoided. In general, cultural practices which facilitate quick draining of the surface moisture of bark are very desirable, e.g. grooming of trees (SATCHUTHANANTHAVALE, 1971).

c. Susceptibility of planting material. Some clones are highly susceptible to both leaf and panel infection, whilst others are severely affected by the leaf fall phase of the disease but rather resistent to panel infections or vice versa (PERIES and DANTANARAYANA, 1966). There is no significant relationship between susceptibility to black thread and the following bark characteristics: thickness, water-holding capacity, size of cells, number of crystal bearing cells, number of latex vessels, number of fibres and stone cells, phenol content (PERIES, 1966 B). Some clones which are in Malaya highly susceptible to black thread are PB 86, PR 107, RRIM 600 and RRIM 605 (CHEE, 1970), whilst GT 1 is of low susceptibility (ANON., 1971). BD 5 is another highly susceptible clone and was for this reason no longer recommended for planting in Indonesia (TIDEMAN, 1955). In Liberia, heavy black thread infections were observed in the clones BD 5, Tjir 16 and AVROS 49 (SPANGLER and MCINDOE, 1949); extremely susceptible was the clone TK 12 (DARLEY and SILVERBORG, 1952).

d. Depth of tapping. HEUBEL (1940), VAN SCHOONNEVELDT (1950) and TIDEMAN (1955) are of the opinion that black thread is favoured by deep tapping, whilst SHARPLES (1936) reported that results on lightly tapped and deeply tapped bark showed no appreciable difference in percentage infection in Malaya.

e. Height of tapping above the ground. It is generally accepted that black thread becomes more severe when the tapping cut approaches ground level (ANON., 1970 A; STEINMANN, 1925, p. 42).

f. Tapping system. According to HEUBEL (1940), black thread is a greater problem in daily periodic tapping systems than in alternate daily tapping; an advantage of alternate daily tapping is that more time is available for control measures (on rest days). DARLEY and SILVERBORG (1952) found that disease incidence was much lower on trees tapped full-spiral fourth daily when compared with trees tapped half-spiral alternate daily. Results of their inoculation trials indicated that once the disease is established, the fourth daily system retards further development of the disease. The above observations suggest that damage is reduced with longer intervals between tappings. This being so, in daily periodic tapping, though the disease is given optimal chances during the tapping period, its further spread should be retarded most effectively during the resting periods.

g. Tapper's influence. BEELEY mentioned in 1929 that the tapping knife and the tapper's hands are perhaps the chief factors in the spread of the disease. DARLEY and SILVERBORG (1952) concluded from experimental results that the disease is spread by the tapping knife but not to a serious extent. PERIES (1966 B) stressed the point that dispersal of the disease is also by the tapper's hands, while removing scrap (= tree lace). It was reported recently that field experiments and experimental evidence have shown that tapping knives do not carry the disease from tree to tree (ANON., 1970 A). As a matter of fact not much progress has been made to clarify this matter since BELGRAVE and DE LA MARE NORRIS reported already in 1917: 'It has been found that the path of spread of black stripe often coincides with the path of the tapper'. Disinfection of tapping knives was little effective, and they draw the conclusion: 'This failure indicates other means of distribution to be active, of these, the one which most readily suggests itself, is spread by the tappers' hands, which almost inevitably come in contact with the diseased surface'.

4.2.2. *Climatic conditions and microclimate*

During 1967 and 1968 black thread incidence was evaluated on portions of renewing bark, tapped in different months of the rainy season. In these experiments tapping was daily for a whole month, followed by one month rest (tapped in June/August/October or in July/September/November).

1967 experiments: two identical experiments were carried out in the same 1943 BD 5 planting. These experiments were tapped by the same tappers and treatments for black thread control were also the same. The pretreatment damage was of a comparable level. The only difference was that the 2 experiments were tapped in different months. Accordingly, the figures for the 1967 damage should give a fairly accurate indication of the actual disease incidence during the different months. The results of these evaluations (exps 19 and 20) are given in Table 2. For easy comparison, the damage done in each month is also expressed as a percentage of the sum of the damage over 6 months. Rainfall data are also given.

1968 experiments: figures are used of 3 experiments tapped in June/August/October (exps 25–27) and of 3 experiments tapped in July/September/November (exps 28, 29 and 31; these trials are left out of the Appendix, because results of treatments were of no further interest). The 6 experiments were carried out in the same 1948 BD 5 planting. Treatments for black thread control were different, except for the petrolatum Treseal, which treatment was incorporated in all trials. Accordingly, the damage figures in the Treseal tıeatment are used here. Each experiment was tapped by a different tapper, which might have affected the results (some tappers may have applied Treseal more effectively than others). The variation between mean pretreatment damage was also greater compared with the 1967 experiments. Results are also given in Table 2.

The results of these experiments show that in 1967 black thread was most predominant in the months of September and October, and in 1968 in August and September. During the months of June, July and August, rainfall was below average in 1967 and above average in 1968, which might explain the respectively later and earlier peaks in damage, as the disease is favoured by prolonged periods of cool and rainy weather. In June, the disease does hardly any damage in general, although rainfall is already rather high; however, there are more hours of bright sunshine and temperature is higher in June than in the most rainy months of August and September (Fig. 1). The figures also show that much more damage was done in October than in June, although weather conditions were very much the same. The differences in damage could probably be attributed to a still low production of spores in June and to extension of diseased patches into the October panel from portions tapped in previous months.

In *1964* and *1965* some experiments were carried out on panels, protected against rain with polyethylene rain guards (exps 1 and 6). Also under these con-

TABLE 2. Black thread incidence during different months of the rainy season.

Year	Exp. no.	Pre-treatment damage	Number of trees	Mean black thread damage in month of					
				Jun	Jul	Aug	Sep	Oct	Nov
1967	19	2.07	471	0	–	1.73	–	2.37	–
1967	20	1.98	592	–	0.29	–	3.73	–	0.18
1968	25	2.11	98	0.11	–	1.34	–	0.59	–
1968	26	1.81	68	0.01	–	1.91	–	0.40	–
1968	27	1.91	44	0.10	–	1.39	–	0.38	–
1968	28	0.69	83	–	0.33	–	0.64	–	0.19
1968	29	1,64	50	–	0.43	–	1.06	–	0.42
1968	31	2.29	49	–	0.93	–	2.32	–	0.88
Mean				0.07	0.56	1.55	1.34	0.46	0.50
Disease incidence per month, expressed as percentage of the sum of the damage over 6 months:									
in 1967 experiments				0	3	21	45	29	2
in 1968 experiments				2	12	35	30	10	11
Monthly rainfall in mm:									
in 1967				302	348	318	733	296	152
in 1968				671	507	880	481	420	184
Av. of 1936–1970				407	444	488	596	379	185

ditions new infections were building up and severe damage was done, although somewhat less and later than on panels exposed to rain (Exp. 1: compare treatments 1 and 2 with 3, and treatments 4 and 5 with 6). The fact that in Exp. 6 disease control with Treseal was significantly better under rain guards than on panels exposed to rain, is probably due to more effective application of the fungicide on dry panels.

These results do not meet the expectations of ANON. (1961), who stated that 'the incidence of bark infection should be appreciably reduced by the use of polyethylene rain guards over the tapping panel'. Without application of fungicides, differences in damage were insignificant in most cases in Exp. 1. Under the large rain guards, which hung closely to the stem, there is very little air circulation and relative humidity becomes often 100% as water condenses on the innerside of the plastic. Although the panels under these rain guards were of dry appearance, the microclimate was obviously suitable for infection. It can be concluded that the fungus can start new infection on panels which are not visibly wet.

Lastly, it is worth mentioning that the disease did more damage on the low panel than on the high panel in Exp. 1, which differences were significantly different at the 5% level. These results are in line with observations described in literature (4.2.1.).

4.2.3. *Clonal differences in susceptibility*

Observations to assess clonal differences in susceptibility to black thread should be made in replicated clonal trials and not before trees have been tapped for a number of years. However, the clonal trials of appropriate experimental design were of too recent a date to allow for such observations.

One old experiment contained all clones which were imported in the early thirties; however, the clones were planted in the same sequence in all 4 replicates, Tapping was on second or third bark renewal when the observations were made. Evaluation of black thread damage was hampered by the many tapping wounds on renewing and renewed bark. Therefore, results of these observations are only valuable as indications (Table 3). The figures are means of about 11 trees per plot, replicated 4 times. As usual, the standard of evaluation is running from '0' (no damage) to '6' (maximum damage possible).

Also in commercial plantings, black thread was generally a much greater problem in the clones BD 5 and TK 12 than in the other clones. However, heavy black thread infections can also occur in those plantings, e.g. Tjir 16 and AVROS 49 (4.2.1.).

The locally developed clone Har 1 is probably somewhat less susceptible than BD 5, although also highly susceptible. Evidence was obtained that PR 107 also might belong to the highly susceptible group in Liberia.

It is reported in literature that some clones are severely affected by the leaf fall phase of the disease but rather resistant to panel infections or vice versa (4.2.1.). The same was observed in Liberia. The clones Tjir 16, AVROS 49 and AVROS 50 belong to the highest susceptible group for Phytophthora leaf fall, but are of moderate or below average susceptibility to black thread; the clone BD 5, which is highly susceptible to black thread, is of below average susceptibility to Phytophthora leaf fall.

TABLE 3. Susceptibility to black thread of some Hevea clones.

Clone	Mean black thread damage
War 4	0.1
AVROS 152	0.1
PB 180	0.2
BD 10	0.3
Tjir 1	0.3
Tjir 16	0.3
AVROS 49	0.4
PB 186	0.5
PB 183	0.6
AVROS 50	0.9
AVROS 256	0.9
BD 5	2.6
TK 12	2.6

TABLE 4. Susceptibility to black thread and patch canker of some *Hevea* clones.

Number of clones	Susceptibility to black thread	Percentage of trees with patch canker
2	low	13.5
4	average	16.5
2	high	25.5

Susceptibility to black thread and patch canker often go together, as is shown in Table 4 for some experimental clones. In the clones BD 5 and Har 1, which are highly susceptible to black thread, patch canker is a major problem.

4.2.4. *Correlation between new and old damage*

In Fig. 2, a tapping panel was shown which was severely affected by black thread during 3 consecutive years. It is rather common that the same trees in a planting are attacked each year. This positive correlation between the occurrence of new and old wounds can be demonstrated with the map of 2 adjacent tapping tasks (Fig. 8).

This BD 5 planting was planted in 1956. Tapping was daily periodic (15 days tapping followed by 15 days rest) on virgin bark of the second panel. The second panel was opened in April 1966 at approximately 1.50 m height. Distance between trees was 4–5 m in this square planting.

An entry of 3 or fewer figures stands for a tree, a dash for a vacant planting place and an *x* for a dead tree. A road crossed the lower right half of the planting, which part is left blank. The figures are estimates of black thread damage (0 = no damage; 6 = maximum damage possible). The first figure refers to the damage done in the 1967 rainy season, the second to 1968 and the third figure to the damage done in the 1969 rainy season. Trees which became dry are designated with 1 or 2 commas, e.g. 0'' = dry after 1967 rainy season, 00' = dry after 1968 rainy season, and 000' = dry or getting dry after the 1969 rainy season. In Task 1, for experimental purposes most trees with severe old black thread damage were taken out of tapping in May 1969; these trees were normal producers and not getting dry, and are marked with a dot after the second figure. The upper part of the 2 tasks is bordered by a swamp; the low-lying flat land extended towards the horizontally drawn line (within a distance of 7 to 12 planting places from the swamp). All trees with 1967 damage of level $\geqslant 3$ are encircled with a drawn line (and shaded from left low to right up) and for the same damage in 1968 with a dotted line (and shaded from left up to right down); the areas are blackened when the 2 types of shadings are overlapping.

In particular in Task 1, the 2 shadings overlap frequently, indicating that trees with old damage have a greater chance to become affected again in the next rainy season. Evidence of this positive correlation between new and old

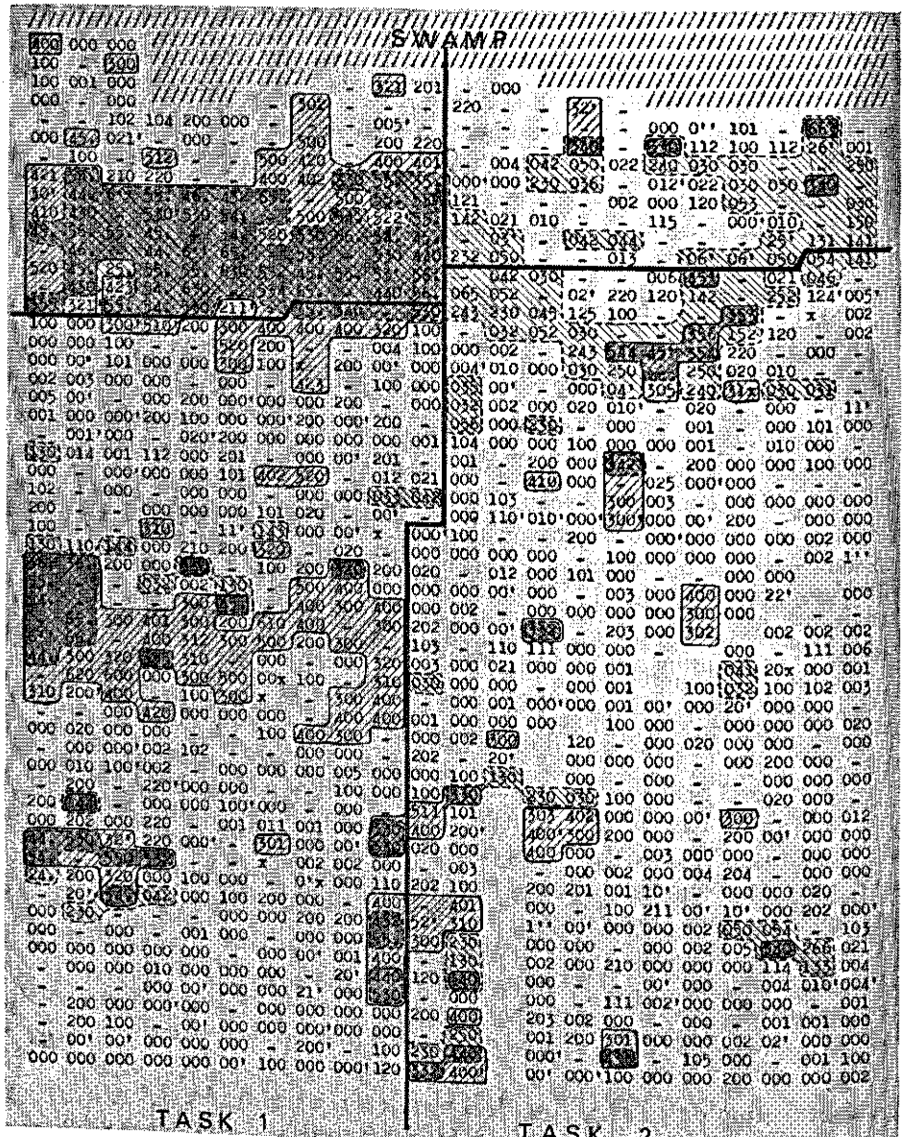


FIG. 8. Black thread damage in 2 tapping tasks during 3 consecutive years.

damage is also given in Table 5, where for the various 1967 disease levels the corresponding 1968 values are given. The values for τ-Kendall show the high significance of the correlation (see: 5.2.2.3.).

4.2.5. *Distribution of black thread trees in a Hevea planting*

The map (Fig. 8) shows that the disease has a distinct tendency to build up in

TABLE 5. Mean 1968 black thread damage for trees of different 1967 disease levels in the 2 tapping tasks shown in Fig. 8.

1967	1968	
	Task 1	Task 2
0	0.16	0.69
1	0.63	1.14
2	0.57	1.85
3	1.79	1.96
4	2.04	1.46
5	3.31	2.33
6	3.73	6.00
τ_K	+0.53	+0.27

patches. This is most obvious for 1967 damage in Task 1 with one large centre in the low-lying area and another large centre in the middle of the task on higher land.

Black thread incidence was much greater in the low-lying area than on higher land. In such areas adjacent to swamps the microclimate is more humid and the soil often flooded for several days or even weeks in the rainy season. Heavier canopies of leaves (less sunshine on the tapping panel) and more abundant growth of epiphytes on stem and branches (possibly extending the period of water-flow over the panel after rainfall) may contribute to the more humid atmosphere, which favours the disease.

4.2.6. *Tappers' influence*

There is a marked difference in 1967 damage between the 2 tasks in Fig. 8. In Task 1, the mean damage amounted to 1.87 for the 430 producing trees, and in Task 2 to only 0.69 for 444 producing trees.

Tappers were also in charge of black thread control measures and, obviously, in 1967, the tapper in Task 2 applied the fungicide Treseal more effectively than the other tapper.

It is interesting to observe the 1967 damage on trees along the borderline of the 2 tasks; along this line many trees were severely affected in Task 1 and very few in Task 2. This might indicate that the disease is spread from tree to tree mainly by the tapper, rather than by rain or wind. Some evidence of this was also obtained in the experiments under rain guards (exps 1 and 6; see also 4.2.2.). Although rainborne and windborne spores can hardly reach the protected panels because the large aprons hang very closely to the stem, the panels became nevertheless infected. The aprons are lifted up for a short moment only during tapping. Therefore it is logical to assume that under such conditions the disease is mainly spread by the tapper with his hands or tapping knife. Another possibility is that old black thread wounds, enclosed by the rain guard, are a source of infection; however, on the trees tapped on high panel in Exp. 1 there were no old wounds above the tapping cut as tapping was in virgin bark.

Also in literature it is generally believed that the tapper is a factor in the spread of the disease from tree to tree. However, when the role of the tapping knife is discussed, it is sometimes ignored that the tapper can probably spread the disease also in other ways, e.g. with his hands. Therefore, the conclusion of DARLEY and SILVERBORG (see 4.2.1.) that the disease can be spread by the tapping knife, should read that the disease can be spread by the tapper in one way or another. Also the conclusion of ANON. (1965) may be at fault that 'it is wise to institute a system of disinfection of tapping knives as soon as an outbreak is known to have occurred', which recommendation is only based on the observation or theory that 'it is only reasonable to expect panel diseases to be spread by tappers'. If the tapper's hands are a more important factor than the tapping knife, then such measures will have little effect.

4.2.7. *Effect of taking out of tapping the trees with severe old damage on general disease incidence*

It is generally recommended to take trees out of tapping when severe infections are building up until the period of wet weather has ceased, to prevent further spread of the disease (BEELEY, 1929; HILTON, 1959, p. 66). Another approach is to stop tapping of trees with severe old damage at the beginning of the rainy season as, in view of the positive correlation between new and old damage, such a measure should lower the disease incidence during the rainy season. Thus in this case the trees are taken out of tapping already before new infections can occur.

The effects of such a measure were studied in the 2 tapping tasks of Fig. 8. It has been said before that in Task 1 all trees with severe old damage were taken out of tapping in May 1969. These trees are marked with a dot after the second figure (see also 4.2.4.). In Task 2 all trees were normally tapped in 1969 to allow for comparison of disease levels. However, comparable groups of trees should be used for these calculations. Therefore, proportional numbers of trees with regard to old damage were omitted from the calculations for Task 2. Various data on these 2 tapping tasks are compiled in Table 6.

For comparison of 1969 disease levels between tasks, the mean damage to the trees of horizontals 6+8+9 (in Table 6) was calculated; these data, along with 1967 and 1968 damage figures, are given in Table 7.

The figures show that in 1969 the disease incidence in Task 1 dropped to 0.39 and that in Task 2 the disease did more damage than in the previous year. However, it cannot be concluded from this experiment that taking out of tapping of trees with severe old damage was the main factor contributing to better disease control in Task 1 when compared with Task 2, as the tapper's influence is unknown (it is not known whether the 2 tasks were tapped by the same tappers during these years). How great the tapper's influence (or other effects) can be is seen when figures for 1967 and 1968 are compared; in Task 1 the damage was more than halved in 1968 when compared with the previous year while the disease incidence remained on the same level in Task 2.

It may be assumed that such sanitation measures may have a beneficial effect

TABLE 6. Miscellaneous data on tasks 1 and 2, derived from Fig. 8.

	Task 1				Task 2			
	number of trees	mean black thread damage in:			number of trees	mean black thread damage in:		
		1967	1968	1969		1967	1968	1969
1. vacant planting places in 1967	128	–	–	–	135	–	–	–
2. trees died in 1967	4	–	–	–	1	–	–	–
3. trees died in 1969	2	0	0	–	2	2.50	0.50	–
4. dry trees before 1968 rainy season	3	6.00	–	–	3	0.67	–	–
5. new cases of dry trees before 1969 rainy season	21	1.10	0.57	–	30	1.10	1.80	–
6. new cases of dry trees before 1970 rainy season	27	1.33	0.56	0.41	26	0.73	0.50	0.88
7. producing trees, taken out of tapping in May 1969 (1968 disease level ⩾ 4)*	50	4.54	4.88	–	35	1.40	4.71	2.06
8. other trees with 1968 disease level ⩾ 4	13	2.62	4.23	1.92	10	1.30	4.20	1.80
9. remaining trees	314	1.48	0.46	0.33	338	0.54	0.49	0.69
Total planting places	562				580			

* In Task 2 these trees were not taken out of tapping but left out the calculations for comparison of 1969 disease levels between tasks.

TABLE 7. Effect of taking out of tapping the trees with severe old damage on general disease incidence. Compare 1969 damage with 1968 damage; Task 2 is the untreated control.

Task no.	Number of trees	Mean black thread damage		
		1967	1968	1969
1	354	1.51	0.61	0.39
2	374	0.58	0.59	0.74

on the general disease incidence, as the disease usually builds up each year on trees with severe old damage. Sources of infection for neighbouring trees are more or less eliminated when such trees are not tapped during the rainy season. Some evidence of this was also obtained in practice in a BD 5 planting of 600 hectares. This planting had a very severe black thread history and all trees with severe old damage were taken out of tapping during an entire rainy season. In that year – and also in later years when all trees were normally tapped again – the disease was no longer a problem in this planting. However, since that year the more effective fungicide captafol was used instead of Treseal for regular black thread control, which measure also might have contributed to better disease control.

The above results indicate that in areas, where normal disease control measures failed in the past, it might be worth trying to take all trees with severe old damage out of tapping before the onset of the rainy season, until the period of wet weather has ceased. When such measures are not taken before new infections have occurred, this method might be less effective as the disease sometimes spreads very rapidly.

4.2.8. *Effect of disinfection of old black thread wounds on disease incidence*

In a field experiment it was tested whether disinfection of old black thread wounds prevents new infections, because of the correlation between new and old damage. The experiment was carried out in a BD 5 planting, tapped monthly periodic on second bark renewal at approximately 125 cm above the union. A panel change was made at the beginning of the previous year.

In July 1966, old wounds on the 1965 panel were cleaned and coated with a 50% dilution of Santar A (see 5.2.3.) in water. Healed wounds were also treated. Dead and diseased bark layers were scraped off and Santar A was brushed on to the scraped surface. Coatings with Santar A are complete and rainfast. Scraped off pieces of bark were collected and removed from the field.

The experiment was done in 2 tapping tasks. In each task all wounds on the 1965 panels were disinfected in 4 adjacent lines and trees of 4 other adjacent lines were left untreated. All trees were rubbed with Treseal during the 1966 rainy season. The results are given in Table 8.

The figures show that under the conditions of this experiment disinfection of old wounds had no noticeable effect on black thread incidence. It can be concluded that the nature of the positive correlation between new and old damage is still not understood. A very hypothetical possibility is that the fungus is transported internally through the dry season panel, without doing damage on its way down. The nearly identical shape of wounds during 3 consecutive years, shown in Fig. 2, gives rise to such speculations. A more likely possibility is that resting stages of the pathogen, present in healed old wounds, become active when such renewed bark is tapped (DARLEY and SILVERBORG isolated the fungus from old wounds; see 4.2.1.). This does not explain, however, the existence of the mentioned positive correlation in the 2 tapping tasks shown in Fig. 8, in which case tapping was on virgin bark. Consideration should also be given to

TABLE 8. Black thread damage on disinfected and untreated control trees.

Treatments	Number of trees	Pretreatment black thread damage (1965)	1966 black thread damage on panels of		
			Jul	Sep	Nov
1965 wounds disinfected	117	2.21	0.37	1.29	0.84
1965 wounds untreated	155	1.85	0.52	1.06	0.56

the realistic possibility that other sources of infection (e.g. pods, leaves, soil) are of greater potential, and predisposing factors are more suitable (e.g. microclimate), in the direct neighbourhood of trees with a severe black thread history.

4.3. Other diseases of the hevea stem, sometimes interfering with black thread

In addition to the data already given on the various diseases of the *Hevea* tree (3), some more detailed information is given below on those which can cause primary or secondary damage to the tapping panel.

4.3.1. *Brown bast*

As its name implies, one of the symptoms is a brownish discolouration of the inner tissue of the bark. In serious cases the wood cambium becomes abnormally active, causing severe burring of the trunk and making subsequent tapping impossible. Flaking of the outer bark is a common symptom in advanced cases as is shown in figs 9 and 10. No latex is produced in the discoloured tissue, nor

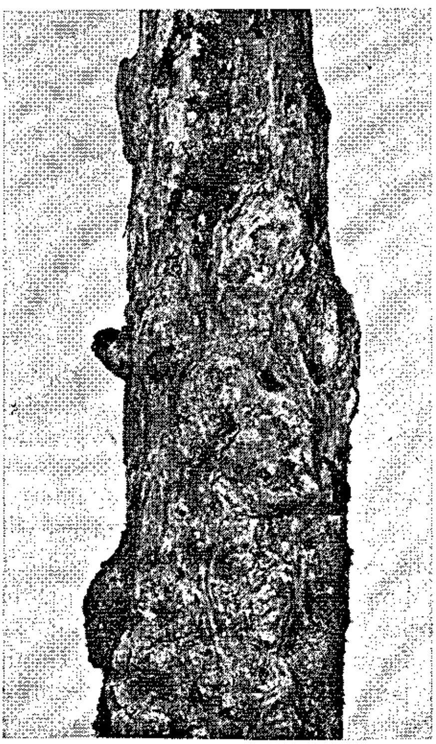


FIG. 9. Stem with typical brown bast symptoms. The scale is 1:9.

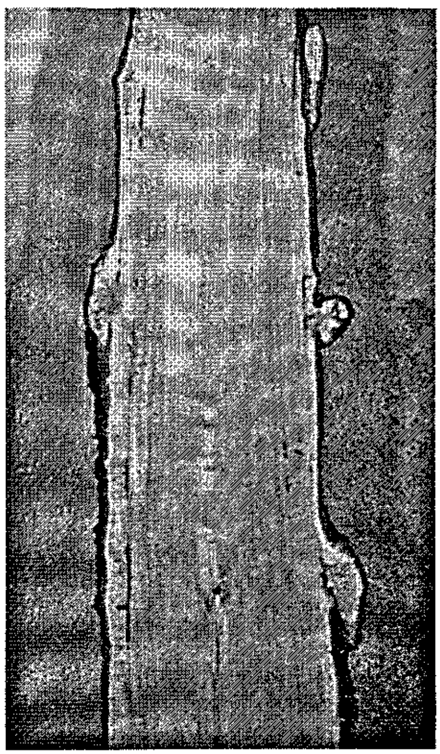


FIG. 10. Overlength section through stem of Fig. 9. The scale is 1:9.

can latex flow through it, so that when the entire cut becomes discoloured the tree becomes dry. Often the trees yield no latex for a short period only without showing the typical brown bast symptoms.

It was previously mentioned that observations were made in 2 tapping tasks with respect to the incidence of black thread and of dry trees (4.2.4. and Fig. 8). Miscellaneous data on these 2 tasks are given in Table 6. An unknown percentage of dry trees were true cases of brown bast. In Table 9 the mean black thread damage is compared between trees which became dry and those which continued to produce normally. The data, presented in Table 6, were used for these calculations. The 'horizontals', mentioned in Table 9, refer to this table.

TABLE 9. Comparison of black thread susceptibility between trees getting dry and normal producers.

	Number of trees	Mean 1968 black thread damage (dry trees became dry after 1968 rainy season and before 1969 rainy season)
Task 1		
dry trees (horizontal 5)	21	0.57
other trees (hor. 6+7+8+9)	404	1.14
Task 2		
dry trees (horizontal 5)	30	1.80
other trees (hor. 6+7+8+9)	409	0.94
	Number of trees	**Mean 1969 black thread damage (dry trees became dry after 1969 rainy season and before 1970 rainy season)**
Task 2		
dry trees (horizontal 6)	26	0.88
other trees (hor. 7+8+9)	383	0.85

The above figures indicate that trees which are getting dry are probably of normal susceptibility to black thread as in the first instance such trees were much less damaged than other trees, in the second instance much more, and in the third the same.

In Fig. 11 the same map is shown as in Fig. 8; however, in this case all trees which became dry are marked (encircled with a line). The spots were blackened when the trees became dry in 1967/'68, shaded when dry in 1968/'69 and left blank when dry in 1969/'70. It is clearly shown that dry trees are much more randomly distributed over the area than black thread trees (compare Fig. 11 with 8). It can also be observed that the incidence of dryness increased with prolonged tapping on the same panel. This panel was opened in 1966 and only 6 trees were dry in 1967 in the 2 tasks. At the beginning of 1969 the total number of dry trees amounted to 57 and at the beginning of 1970 to 110 trees (dry or getting dry).

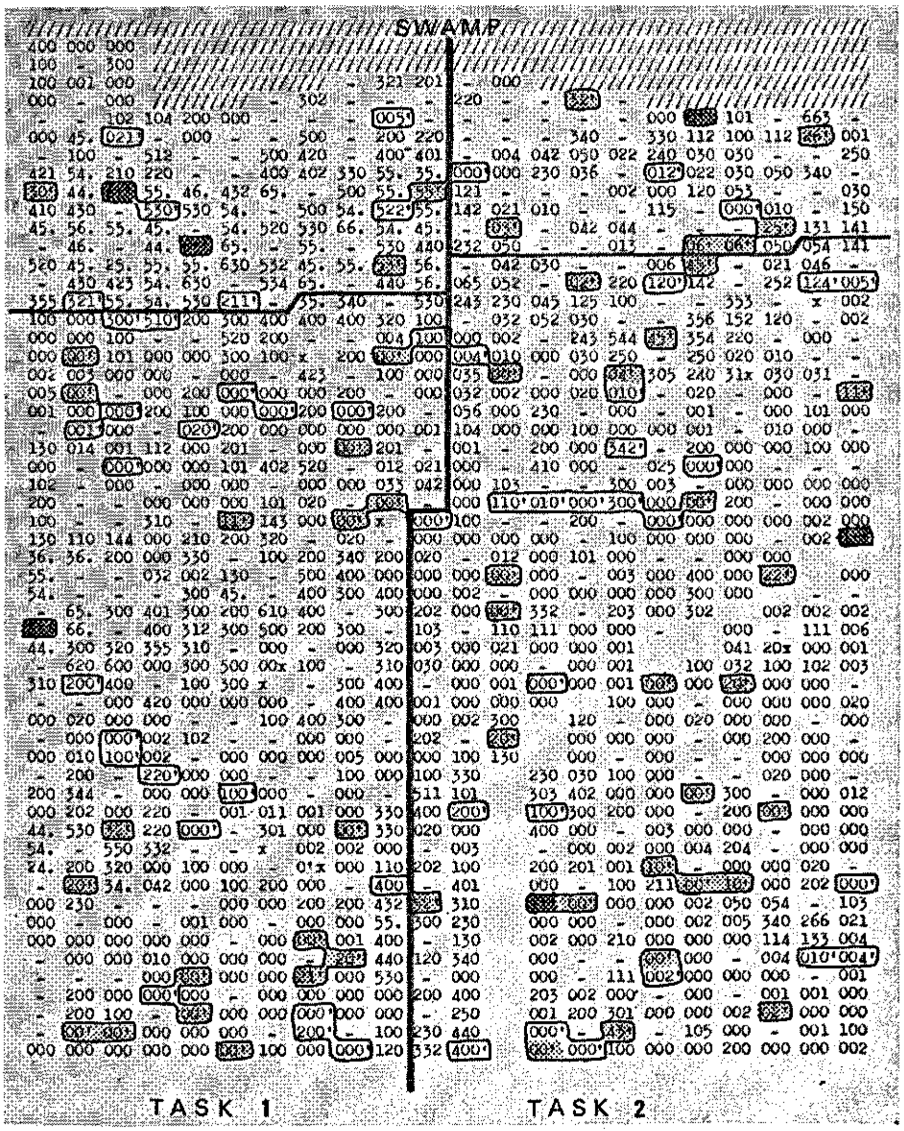


FIG. 11. Incidence of dry trees in 2 tappings tasks during 3 consecutive years.

4.3.2. *Patch canker*

Typical patch canker wounds are not seldom seen on renewing bark, previously damaged by black thread. The infections may occur in early stages of the black thread disease or years later. However, patch canker is not limited to bark damaged by black thread as infections can occur anywhere on the stem, e.g. in wounds made by sprouts, cup wires or slashing iron or in cracks of the bark caused by storms.

For differences in clonal susceptibility to patch canker see 4.2.3. and Table 4.

4.3.3. *Ustulina zonata*

Ustulina is commonly found as a saprophyte on dead wood; as a disease it is rare on trees under about 20 years of age. The fungus causes root, collar and stem rot and finally kills the tree (HILTON, 1959). The fungus is spread by windborne spores and is primarily a wound parasite (ANON., 1954).

It was once observed at Harbel that a group of 10 trees, whose panel marks were severely affected by black thread (4.1.5.), also became infected with *Ustulina*. The fungus probably came as a secondary infection after the primary infection with *Phytophthora palmivora*. On the trunk, shown in Fig. 12, the fungus had spread about 40 cm above the panel mark and downwards to the base of the

FIG. 12. *Hevea* stem, severely affected by *Ustulina zonata*. The fungus probably came as a secondary infection after primary infection with *Phytophthora palmivora* in the panel marked area. Note the strands of coagulated wound latex and the more or less circular shaped, greyish fructifications. The scale is 1:8.

tree or even lower. These symptoms had developed within a year after the new panels were laid. These observations show that under special conditions black thread disease can be followed by *Ustulina* disease.

4.3.4. *Fusarium javanicum*

In the month of December 1970, this fungus had developed a solid white/greyish layer of mycelium and spores on scraped portions of bark below the tapping cut on many trees in several *Hevea* plantings. The cork and outer hard bast layers were scraped off and stimulation was with ethephon in aqueous media. The fungus had developed also on the young renewing bark above the cut. A mild case of such infections is shown in Fig. 13.

The fungus did not penetrate deeply into the bark, although there was some necrosis in the outer layers. The fungus is probably of secondary nature and lesions, which had developed above the cut, were more likely caused by black thread.

Phytophthora and *Fusarium* are often associated in rubber. WEIR (1926) makes mention of a *Fusarium* sp. which was found on *Hevea*-fruits, parasitized by *Phytophthora* in the Amazon region. BEELEY (1929) reported that *Fusarium* is often found immediately above cuts, affected by black thread. Also DARLEY and SILVERBORG (1952) isolated *Fusarium* from bark, diseased by *Phytophthora palmivora*.

FIG. 13. Colonies of *Fusarium javanicum* immediately above the tapping cut and on scraped portions of bark below the cut. The scale is 1:5.

5. CONTROL OF BLACK THREAD

5.1. General information

In *Hevea* plantings, susceptible to black thread, the tapping panel should be regularly treated with fungicides during the period of wet weather. Other measures, discussed below, might lower the disease incidence, but regular application of fungicides is still required.

A measure which is likely to be effective to some extent is to stop tapping of those trees during the wet season, which were severely affected by black thread in the previous rainy season (4.2.7.). In 1929 it was already recommended by Beeley to take trees out of tapping after the first signs of new infections. A very effective measure is – of course – to discontinue tapping on all trees during the susceptible period; however, in general, this period lasts at least several months. The loss of crop makes this measure unacceptable if there are alternatives.

Cultural measures, which create a less damp microclimate around the tapping panel and facilitate quick draining of surface moisture of the bark will probably prevent optimum spread of the disease (4.2.1.), e.g. pruning of low hanging branches and grooming of the stem.

Disinfection of tapping knives became common practice in some countries, because the tapper might be the main factor in the spread of the disease from tree to tree (4.2.6.). Beeley (1929) went as far as to recommend that 'immediately an area has become infected with the black stripe fungus all knives, scrap sacks, spouts, and cups should be sterilized and cleaned in disinfectant solution'. However, recently some evidence was obtained by Anon. (1970 A) that tapping knives do not carry the disease from tree to tree (4.2.1.). The possibility remains, which is worth investigating, that the tapper can spread the disease in other ways, e.g. with his hands; however, disinfection of hands after tapping of each tree is practically impossible.

Peries (1969) mentioned the theoretical possibility that chemical treatment of the soil may be a useful approach, provided the pathogen – present in the soil – is a source of infection.

Special panel dressings are sometimes applied as a curative measure, in addition to regular treatment with fungicides. It is questionable, however, whether the recommended products are of much use in arresting further development of diseased patches as they do not penetrate deeply into the bark; to quote Deconinck (1968): 'it is exceedingly risky to hope that a coat of fungicide paint applied to the outside can have any effect on the internal parasite'.

Preventive treatments with fungicides of recently tapped bark have been applied since the earlier days of *Hevea* growing. Belgrave and De la Mare Norris recommended already in 1917 the use of Carbolinium, Izal and Brunolinium for black stripe control. SHARPLES (1936, p. 434–447) recommended coal tar, coal tar derivatives emulsifiable with water, and mixtures of tars and tar derivatives with wax, oils or fats. Coal tar consists of a considerable number of organic compounds, amongst which are benzene, toluene, naphthalene and phenols. STEINMANN (p. 42–47) mentioned these products already in 1925 and preferred the emulsifiable coal tar derivatives for black thread control, e.g. Carbolineum plantarium (5%), Brunolinum plantarium (5%), Agrisol (5–10%) and Izal (3%), all of them still known names in rubber. Higher concentrations were recommended for curative treatments (5% for Izal and 20% for the others). VAN SCHOONNEVELDT (1950) recommended a mixture of the greasy substance Socony 2295 A with 3% Carbolineum plantarium.

DARLEY and SILVERBORG (1952) tested in Liberia some newer fungicides, amongst which were a dithiocarbamate and an organic mercury compound. Most compromising results were obtained with the petrolatum Socony 487.2 (= Waxrex Treseal), a fatty semisolid mixture of paraffin hydrocarbons. CARPENTER (1954) reported that captan was the most promising fungicide among 22 others in preliminary field tests in Costa Rica. Phenyl mercury acetate was also strongly fungicidal but with too narrow limits between effective control (0.2%) and phytotoxicity (0.25%).

RIGGENBACH (1959) tested in Ceylon a number of fungicides. Older products, such as Izal and Brunolinum plantarium, were little effective in in vitro tests against *Phytophthora palmivora*. Also DECONINCK (1968) reported that these products have a very slight toxicity towards fungi. Fylomac 90 (tetradecyl pyridinium bromide), captan and copper compounds were evaluated as fairly effective, and Antimucin (active ingredient: phenyl mercury acetate) as outstandingly effective in RIGGENBACH's tests (in vitro and in the field). Since that time Antimucin has been widely used in the Far East, applied in concentrations of 0.5–0.8% of the commercial formulation in water. The commercial formulation contains 10% metallic meicury.

The Antimucin WBR formulation also contains a red dye to make application to the panel visible, and thus facilitate field supervision. For the same purpose, STEINMANN (1925, p. 46) reported that 3% CaO or 0.1% fuchsine can be added to Izal dilutions in water. SHARPLES (1936, p. 437) mentioned that the manufacturer of Izal recommended 1% methylene blue as colouring agent. Antimucin is generally applied daily or every second day with a brush or sprayer (ANON., 1963).

In bio-assays, carried out in Liberia, the strongest fungitoxicities against *Phytophthora palmivora* were shown by an organic mercury compound, cycloheximide, captafol (Difolatan) and captan, arranged in order of decreasing effectivity. Among the other 15 fungicides tested were thiram, dithiocarbamates and triphenyl tin acetate (SCHREURS, 1969). In field experiments, satisfactory results and better disease control were obtained with 1–1.25% Difolatan 80 WP in water in weekly applications than with other tested products. Antimucin failed to give good protection in concentrations of 0.6–1% under these conditions (SCHREURS, 1969 and 1971). A suitable colouring agent to check upon the application of Difolatan 80 WP appeared to be yellow iron oxide; however, Sterox NJ – a synthetic detergent – should be added to obtain stable suspensions. It was further recommended that a slurry of the Difolatan powder should first be prepared, but if too much water is added, the aggregated Difolatan particles do not separate and an unstable suspension is immediately obtained. Some sticker was also added to such mixtures, although it has not been proved that the effectiveness of Difolatan suspensions is improved by this admixture. According to CHEE (1970), sticking agents used as adjuvants to fungicides for black stripe control had little beneficial effect.

Later on, captafol was also tested in Malaya. CHEE (1970) reported that among 20 fungicides tested, organo-mercurials (0.5% Antimucin WBR, 0.5% LPF XXI and 5% Kroma-clor), captafol (2% Difolatan), chloroneb (0.5% Demosan), drazoxolon (0.25% Mil-col) and cycloheximide (0.5% Acti-dione) were effective against black stripe when applied after every tapping. He concluded that the considerably lower mammalian toxicity of Acti-dione and Difolatan makes them preferable to other compounds. In these trials, the flowable formulation of Difolatan gave better control than the wettable powder at the same dilution, although containing about half the amount of active ingredient. CHEE concluded that this flowable formulation is probably a better bark penetrant. Lastly, CHEE mentioned that the following fungicides have shown promise when applied at weekly intervals: K 905 (a zinc fungicide in spindle oil), diluted to 5% in coconut oil, and Tectal T 10 (zinc naphthenate), diluted to 1% in palm oil. The latter formulation shows promise as a prophylactic applied weekly below the tapping cut. It is of interest to know that mouldy rot, another important tapping panel disease in the Far East, caused by the fungus *Ceratocystis fimbriata*, can be controlled effectively with 2 weekly applications of benomyl (0.5% Benlate), cycloheximide (0.5% Acti-dione) and captafol (2% Difolatan), according to CHEE (1970).

Further details on results, obtained with captafol and other fungicides in Liberia for black thread control, are given below. Data are also given on possible side effects of the applications, e.g. on rubber production. Where necessary for easy reading, some of earlier published results are reported again.

5.2. MATERIALS AND METHODS

5.2.1. *Bio-assays*

In bio-assays fungicides were tested for inhibition of mycelium growth of *P. palmivora* (SCHREURS, 1969). The fungicides were mixed in 15 ml of oatmeal agar (2% oatmeal, 2% agar, pH 6.7) per Petri dish. The plates were inoculated in the centre with a 7 mm disc of young mycelium. Incubation was up to 6 days at 26 °C., whereafter mycelium growth was measured (5.3.).

The bio-assay, described by WELTZIEN (1958), was greatly altered and used to determine captafol content in samples field latex (5.5.8.1.). At first captafol suspensions (Difolatan 80 WP) in water were tested. A droplet of the suspension is allowed to flow out on a filter paper. After evaporation of the water a spore suspension of the test fungus *Glomerella cingulata* (10^7 spores/ml) in nutrient solution is sprayed onto the filter paper. Incubation is for 48 hours at 24°C in a moist atmosphere, whereafter the papers are dipped in alcohol 96% and results are evaluated. Fungus growth (the spores) gives the paper a brownish/orange colour; the spots where the fungicide suppressed germination show up white.

Under these conditions, captafol suspensions inhibited germination completely in 10 ppm, started failing in 2.5 ppm and had no noticeable effect in 1 ppm. To determine the captafol content in latex, the latex should first be diluted with water to allow for flow out of the droplet on the filter paper. One volume latex was diluted with 3 volumes of water and pH adjusted to 6.5. Consequently, 10 ppm captafol in field latex is the lowest determinable concentration with this method as, because of dilution, the tested droplets contain only 2.5 ppm.

5.2.2. *Field experiments*

5.2.2.1. Application technique

The fungicides were applied on a band of 2–2.5 cm wide immediately above the tapping cut. Petroleum jellies were applied with the finger and liquid fungicides by a 1-inch-wide brush. On the average, approximately 2 g petroleum jelly and 3 ml of liquid fungicides were used per tree per application.

Application was once or twice a week in most experiments. In periodic tapping, fungicides were applied after tapping in the early afternoon and each tapping period was concluded with a last application during the first days of the resting period. When tapping was on alternate days the applications were made on the resting days. Applications were postponed for one or more days when it was raining at application time and water was running down the tapping panel. However, in the middle of the rainy season applications had quite often to be made on rather wet panels.

Glass jars were used as container for liquid fungicides in small scale experiments. Plastic buckets of 5 l capacity – and filled up for not more than one/third – proved to be very suitable for large scale use as spillage was avoided (treatment of all trees of a tapping task required 1 to 1.5 l). Fungicide suspensions, requiring regular agitation, could also easily be stirred with the brush in such buckets.

It is sometimes recommended to apply the fungicide also to a band immediately below the tapping cut and to remove the tree lace before application (ANON., 1970 A); these measures were not taken in the described experiments.

5.2.2.2. Experimental design

The close positive correlation between occurrence of new and old black thread damage was discussed before (4.2.4.). Therefore, it is very important that field experiments for black thread control are laid out so that the damage done in previous black thread seasons is of the same level in all treatments, in order to level the chances of infection (SCHREURS, 1969).

Results of fungicide applications depend also on the applicator (4.2.6.). Accordingly – if possible – application of all treatments should be made by the same person. In larger scale trials – when applications have to be made by more people – in theory each worker should treat a proportional number of trees of each treatment; however, for practical reasons, treatments and applicators were alternated in such instances during consecutive applications.

A last factor worth mentioning is that the degree of disease control obtained is influenced by disease incidence on neighbouring trees (4.2.6.).

Replicated tree plot design (each tree is a plot) has the great advantage that optimum care can be taken for equal distribution of trees with different old damage over the various treatments. A disadvantage is that application of treatments is time-consuming and mistakes can easily be made as the trees of each treatment are scattered over the entire experimental field. This design was only used when yield figures were also wanted.

The experiments were of randomized block design when yield figures were not collected. The number of replicates was at least 3 in most of these experiments. Each plot was a line with a certain number of neighbouring trees. Care was taken that pretreatment damage was of the same level for all treatments.

5.2.2.3. Statistical analysis

An analysis of variance was applied to the damage figures, collected in experiments with replicated tree plot or randomized block design.

In the tables in the Appendix the calculated standard error of a treatment mean is given (denoted: S_m); also recorded are the degrees of freedom on which this standard error is based (denoted: n_2). Significance of differences was calculated as follows. First, special values were copied from a table with 'significant studentized ranges' for a 5% level test for the required sample sizes and degrees of freedom. Next, each value was multiplied with the S_m factor, to form the 'shortest significant ranges'. Upon this, the treatment means were listed in ranked order and the means, which were not significantly different, were connected with a line. Details on this 'multiple range test' are given by DUNCAN (1955). In tables, treatments and results are listed in order of most to least effective and, *any 2 means, not connected by the same line, are significantly different at the 5% level.*

In experiments with replicated tree plot design, each tree is a plot and blocking on paper for statistical analysis is according to pretreatment damage (block 1 contains the tree of each treatment with the most severe old damage, block 2 the second tree in line, et cetera). Such experiments are nos. 8, 11, 16, 23 and 35.

In experiments of randomized block design, the mean damage per plot was at first calculated; these mean values were statistically analysed (exps 1, 6, 18, 21 and 37).

Some experiments were incomplete and unbalanced randomized block designs with calibration (exps 19, 20, 25, 26 and 27). These were analysed by means of regression analysis and the SCHEFFÉ criterion was used to test differences between treatments (SCHEFFÉ, 1959).

The calibration variate, i.e. old black thread damage, turned out to be significant with a positive regression coefficient, except in Exp. 25. In Exp. 25 the estimated regression coefficient was negative; hence the calibration variate was dropped and an analysis of variance was applied. Results of these experiments are presented in 2 tables. In the first table the mean evaluated damage of all trees per treatment is given (old and new damage), and also some information on distribution of plots over tapping tasks and blocks. The second table contains estimates of damage, adjusted for differences in pretreatment damage and for incomplete and/or unbalanced distribution of treatments over tapping tasks or blocks. For differences between treatments see the t values. The calculated SCHEFFÉ value is a measure for the significance of the t values. As usual, treatment means which are not significantly different, are connected with a line.

In another experiment (see 4.2.4.), an estimation of the significance of correlation was wanted between new and old damage (1968 damage compared with 1967 damage on the same trees). The collected data are estimation figures. As a result of lack of validity of the assumption of a bivariate *normal* distribution, the distribution-free measure of correlation τ_K was used (KENDALL, 1948, chapter 3).

5.2.3. *Products used and their sources*

Fungicides

captafol: Difolatan 80 WP and Difolatan-4-flowable (48%): Chevron Chemical Co., previously known as California Chemical Co., San Francisco, USA

captan: Orthocide 406, 50% w.p.: California Chemical Co.

coal tar derivatives: Agrisol Vulcan Red: Solignum Ltd., Dagenham, England; Brunolinum Plantarium: The Standardized Disinfectants Co., London, England.

copper compounds: COCS, containing 55% Cu as basic sulfates and chlorides: Niagara Chemical Div., Middleport, USA

dithiocarbamates:

ferbam: Fermate 76% w.p.: Dupont de Nemours & Co., Wilmington, USA

zineb: Polyram Z, 70% w.p.: BASF, A.G., Ludwichshafen/Rhein, Germany

folpet: Phaltan 50% w.p.: California Chemical Co.

organic mercury compounds: Antimucin WBR (10% metallic Hg): Sandoz Ltd., Basel, Switzerland; Mycocide Latex (12% metallic Hg): Procida, Paris, France

organic tin compound: Duter 20% w.p. (triphenyl tin hydroxide): N.V. Philips Duphar, Amsterdam, the Netherlands

petroleum jellies: Waxrex Treseal: Mobil Oil Co., London, England; Shell TB 192: Shell, London, England; Petrolatum Texaco 1234: Texaco Africa Ltd., Monrovia, Liberia

thiram: Thylate 65% w.p.: Dupont de Nemours & Co.

Antibiotics

anisomycin (probably pure compound): Pfizer International Inc., New York, USA

cycloheximide: Acti-dione RZ (1.3% w.p.): Upjohn International Inc., Kalamazoo, USA

griseofulvin (microcrystalline): Mc Neil Laboratories Inc., Fort Washington, USA

streptomycin: Fytostrep, containing 0.4% streptomycin-sulfate: Kon. Ned. Gist- en Spiritusfabriek N.V., Delft, the Netherlands

Stickers, wetting agents and detergents

Agral wetting agent: Plant Protection Ltd., Fernhurst, England

Mobilcer Q and *Mobilcer 67* (wax emulsions): Mobil Oil Co.

Ortho Spray Sticker: Chevron Chemical Co.

Plyac spreader/sticker: Allied Chemical and Dye Corporation, Morristown, USA

Santar A (a paste, containing 3% HgO, recommended by producer as panel dressing after Antimucin applications; in experiments mainly used to increase sticking of captafol): Sandoz Ltd.

Sterox NJ (synthetic detergent): Monsanto Co., St. Louis, USA

XRD-24 (emulsified Waxrex Treseal, in experiments used to increase sticking of captafol): Mobil Oil Co.

Colouring agents

Panelred (red additive, recommended by producer to improve visibility of Antimucin treatments): Sandoz Ltd.

Yellow iron oxide (YO-2087): Pfizer Overseas Inc., New York, USA

The concentrations in text and tables refer to the commercial formulation for coal tar derivatives, COCS, organic mercury compounds, petroleum jellies, colouring agents, stickers, wetting agents and detergents; concentrations of all other products are based on active ingredient. The names of Ortho Spray Sticker, Sterox NJ and Waxrex Treseal – often used in text and tables – are shortened to Ortho sticker, Sterox and Treseal, respectively. The Difolatan 80 WP formulation of captafol was used, unless stated otherwise. Captafol is N-(1,1,2,2-tetrachloroethylsulfenyl)-cis Δ 4-cyclohexene-1,2-dicarboximide. The average diameter of captafol particles is 2 μ in Difolatan 80 WP formulation and 1.5 μ in the Difolatan-4-flowable formulation. Treseal is a petrolatum, a fatty semisolid mixture of paraffin hydrocarbons.

5.3. Results of screening of fungicides in bio-assays

Complete inhibition of mycelium growth of *P. palmivora* was obtained when 100 ppm of the following fungicides were mixed with culture media: captafol, captan, copper compound (COCS), cycloheximide and organic mercury compounds, observed 6 days after inoculation of the plates. Among the other fungicides tested were a coal tar derivative (Agrisol), dithiocarbamates (ferbam and zineb), folpet, thiram, triphenyl tin hydroxide and some antibiotics (anisomycin, griseofulvin and streptomycin).

Results of further tests with captafol, captan and organic mercury compounds are given in Table 10. COCS and cycloheximide were not further tested for the following reasons. Contamination of latex with copper compounds affects physical properties of rubber (EATON, 1935) and therefore, copper compounds cannot safely be used on tapping panels. COHEN (1950) reported that the antibiotic cycloheximide – although remarkably fungitoxic to *P. palmivora* on culture media – did not suppress growth of the fungus when sprayed on *Hevea* stems in concentrations up to 100 ppm. However, CHEE reported in 1970 that promising results were obtained with this antibiotic in field experiments (5.1.).

Results of this experiment, carried out in duplicate, show that captafol is a more potent fungicide against this fungus than captan; organic mercury compounds were most effective.

TABLE 10. Mycelium growth of *Phytophthora palmivora* in mm after 6 days on culture media, containing 10 ppm fungicide.

Fungicide	mm growth
organic mercury compounds	0
captafol	3
captan	33
untreated control	44

5.4. RESULTS OF FIRST FIELD-SCREENING OF FUNGICIDES ON PANELS PROTECTED AGAINST RAIN

This field trial was designed to find out whether satisfactory disease control could be obtained with some liquid fungicides and with Treseal when mixed with promising fungicides (Exp. 6). Although results have been published already (SCHREURS, 1969), the experiment is reported again to link results of bioassays with field trials carried out later.

The panels were protected against rain with polyethylene sheets. This prevented the actual differences among fungicides being masked by their varying rainfastness.

Disease control with 1% captafol suspension was significantly better than with Treseal, captan or Mycocide; there were almost no signs of infection on these captafol treated panels. Incorporation of captan or captafol into Treseal had little effect.

In view of the above results, captafol suspensions were further tested under normal field conditions, which was on panels exposed to rain.

5.5. RESULTS OF FIELD EXPERIMENTS WITH THE FUNGICIDE CAPTAFOL ON PANELS EXPOSED TO RAIN

5.5.1. *Captafol compared with other fungicides*

In Table 11 results are summarized of most experiments in which 1% capta-

TABLE 11. Black thread control with different fungicides.

Treatments	Mean black thread damage in Exp. no.								
	8	16	18	19	20	23	35		37
							('69)	('70)	
1% captafol	1.05	1.15	0.50	1.09	1.29	0.59	2.00	0.22	2.25
Treseal	1.95	0.94	1.06	2.29	1.78	2.59	2.94	0.13	1.88
0.6–1% Antimucin	–	1.75	2.11	1.67	2.31	–	4.07	1.83	3.80
untreated control	2.98	1.90	2.16	3.35	2.88	–	–	–	–

Ortho sticker (0.1%) was added to the captafol suspensions in water, and a wax emulsion (5%) to the Antimucin solutions in water in exps 35 and 37. Antimucin was tested in 0.6% concentration in Exp. 20, in 0.8% in exps 16, 18 and 19, and in 1% in exps 35 and 37. In Exp. 20, captafol was actually tested in 0.8% concentration.

fol +0.1% Ortho sticker in water is compared with Treseal. Data on Antimucin and untreated controls are included. Details, e.g. on significance of differences, are to be found in the Appendix.

With a few exceptions, captafol and Treseal gave significantly better disease control than Antimucin and the untreated control; disease control with Antimucin was very unsatisfactory when applied once or twice a week.

In exps 8, 18, 19, 20 and 23, captafol was significantly more effective than Treseal; in the other experiments (16, 35 and 37) differences were insignificant. Unsatisfactory disease control obtained with captafol in exps 35 (in 1969) and 37, is probably connected with prolonged storage of the suspensions ready for use; accordingly, decomposition of the active ingredient might have taken place.

In Exp. 18, captafol was also compared with the coal tar derivative Brunolinum plantarium and with the petroleum jellies Shell TB 192 and Texaco 1234. Black thread incidence was the lowest in the captafol treatment.

The above results show that, in general, disease was better controlled with captafol than with other fungicides used for black thread control. The figures also show that disease incidence in the captafol treatments was on the average of level 1.13, which low figure indicates that the damage done was negligible (4.1.4.).

5.5.2. *Concentration*

In Exp. 6 – carried out under rain guards – disease incidence was considerably lower on trees treated with 1% captafol suspension than with 0.2% concentration. Fungicides were applied on alternate days. Results suggested, although differences were insignificant at the 5% level, that 0.2% might be too low a concentration for optimum disease control, in particular in actual practice when panels are exposed to rain. Some more evidence of this was obtained in Exp. 25 (weekly applications under normal field conditions). Results with 0.5% captafol and higher concentrations were considerably better than with 0.25% concentration; differences between 0.5%, 1% and 2% captafol were insignificant. In exps 20 and 21 rather satisfactory disease control was obtained with 0.8% captafol suspensions.

The above results indicate that optimum disease control can possibly already be achieved with captafol suspensions in 0.5% concentration. However, 0.5% is probably too close to the critical concentration under Liberian climatic conditions and may not sufficiently allow for loss of residue because of rain (dilution of suspension when application is on panels still wet of previous rainfall or dilution because of rainfall shortly after application). In view of these considerations, 1% captafol suspension became the standard concentration, which has proved to be very effective, both, in experiments (Table 11) and in commercial practice.

5.5.3. *Stickers*

Ortho sticker (0.1% and 0.5%) and emulsified Treseal (1% and 10% XRD-24) were added to captafol suspensions in Exp. 26. The admixtures had no substantial effect on the effectiveness of captafol applications. In Exp. 8, a wax emulsion (25% Mobilcer 67) was added to the captafol suspension. Although such wax emulsions cover the bark completely with a water-repellent film, disease control was not improved. The wax on its own gave no protection at all (Treatment 3). Results of other experiments – which are not reported here – indicated that high concentrations of wax emulsions might even lower the effectiveness of captafol applications, possibly because the captafol particles are embedded in the wax layer, which may inhibit direct contact of captafol with bark and fungus; in other words, the particles are immobilized, which may decrease biological activity.

Santar A was tested in combination with captafol because of its excellent sticking properties. This product is miscible with water and leaves a rainfast coating on the bark after drying up. Results of exps 8, 11 and 16 indicated that this product might have some beneficial effect on the effectiveness of captafol; however, differences in effectiveness were insignificant at the 5% level. On its own, Santar A gave no protection at all in 10% concentration when applied weekly (Exp. 8).

Captafol was not only tested in aqueous suspensions but also in palm oil as carrier. For results see 5.5.6.

In most experiments – and also in commercial practice – 0.1% Ortho sticker was added to the captafol suspensions in water, although it has not been proved that better disease control is obtained. It is doubtful whether they serve any purpose. Also CHEE (1970) found that sticking agents used as adjuvants to fungicides for black thread control had little beneficial effect (5.1.).

5.5.4. *Colouring agents*

Colouring agents are used to make application of fungicides to the panel visible (5.1.). The discovery that yellow iron oxide is a very suitable colouring agent for captafol suspensions in water was previously published (SCHREURS, 1971). The main points are summarized below. In early experiments, the water soluble dye Panelred was added to captafol suspensions. However, with water soluble dyes it is never certain that a proportional amount of a suspended fungicide is applied to the panel, especially when the suspension is not very stable. Therefore insoluble colouring agents of about the same particle size as the fungicide are to be preferred. Yellow iron oxide meets these requirements. In a concentration of 1 %, the panels are coloured distinctly yellow; the product is not washed off by rain, nor does the colour fade. Difolatan 80 WP does not contain enough detergents to keep the yellow powder in suspension; however, when some Sterox is added, stable suspensions are obtained. The mixture most extensively tested in the more recent field experiments contained 1 % captafol (1.25 % Difolatan 80 WP), 1 % yellow iron oxide, 0.1 % Ortho sticker and 0.01 % Sterox.

Results of exps 35 and 37 indicated that these admixtures did not affect fungitoxic properties of captafol suspensions (compare Treatment 5 with 3 for Exp. 35 and Treatment 1 with 4 for Exp. 37). The above formulation with yellow iron oxide and Sterox has proved its usefulness also in commercial practice.

5.5.5. *Frequency of applications*

Generally, satisfactory black thread control was obtained with weekly applications of 1 % captafol suspensions. Young infections, developing on bark tapped after the last application, were killed with the next application.

Different frequencies of applications were tested in exps 27 and 41. In Exp. 27, results were very much the same for once and twice a week application. In Exp. 41 captafol was applied on alternate days and weekly. Although the trees had a rather severe black thread history, there was no new damage at all during these 2 treatments. Main reasons, contributing to the excellent disease control were probably:

a. The very low rainfall. Except for August, monthly rainfall was below average from May through December in 1970.
b. Absence of untreated panels. All trees of the planting were regularly treated with captafol, under which conditions build-up of the disease is kept in check.
c. Punctual application. The quality of the applications was above average in this experiment.

It is likely that the appropriate frequency of applications depends largely on climatic and experimental conditions. Cases of unsatisfactory disease control are probably often caused by interference of rain at application time, especially when little residue adheres to the bark during consecutive applications. Therefore, when the application was of poor quality, the treatment should be repeated in the same week when the normal frequency is once a week.

Observations made in a large-scale experiment indicated that captafol residue on the tapping panel probably gives also some protection to the untreated strip of bark, tapped after the last application. Application of fungicides was stopped towards the end of the rainy season in this trial. Weather conditions were apparantly still suitable for infection as severe damage was done after application was discontinued. However, such damage was restricted to those trees, which had been treated with less effective fungicides; in the captafol treatment, there was considerably less damage on the untreated portion.

5.5.6. *Formulations*

The fungicide captafol is available in 2 formulations for aqueous applications, i.e. an 80% wettable powder and a flowable formulation (containing 48% captafol). The flowable formulation was not extensively tested, one of the reasons being that no physically stable suspensions could be obtained with the colouring agent yellow iron oxide.

The flowable formulation controlled black thread to about the same extent as the wettable powder of captafol under the conditions of Exp. 37. In this experiment, all captafol treatments gave rather unsatisfactory results, probably because of prolonged storage of the suspensions ready for use.

It is worth mentioning that in Exp. 16 black thread damage was lowest in the treatment with 1% captafol in palm oil (2,4-D was also added to this mixture). Such mixtures merit further testing as palm oil is often used as a carrier for yield stimulants; when application is above the cut, admixing of a fungicide might be needed to prevent black thread damage. Although the difference in results between captafol in palm oil and captafol in water was not significant at the 5% level, results did show that captafol might be at least as effective in palm oil as in water. In palm oil, a homogenous dispersion of captafol is much easier obtained with the flowable formulation than with the wettable powder.

5.5.7. *Large-scale field experiments in different Hevea clones in different areas*

During the rainy season of 1968, captafol was used at Harbel Plantation on 3,000 hectares of rubber. The plantation is divided in 45 divisions of 600 to 1,000 ha each. The fungicide captafol was applied on 4 whole divisions, except for plantings stimulated above the cut. Some small-scale plantings on other divisions were also treated.

Application was once a week with 1% captafol + 0.1% Ortho sticker in water; colouring agents were not added. The weekly applications were made from June/July through December. For the 15 days periodic tapping system, application was on the 5th and the 11th tapping day and on the 1st or 2nd resting day; for monthly periodic on the 5th, 12th, 19th and 26th tapping day and on the 1st or 2nd resting day.

Black thread damage was evaluated in the dry season (February/March 1969) and results are given in tables 12 and 13. The damage done in 1968 is roughly compared with 1967 damage (or earlier in some instances) when Treseal was used for black thread control.

Generally, disease control was better in 1968 than in 1967. In 1968 weather conditions were at least as suitable for build-up of the disease as in 1967; monthly rainfall was higher from May through December (except for the month of August) when compared with the corresponding months in 1967. Therefore, the better disease control obtained in 1968 should be attributed to the use of

TABLE 12. Black thread control with captafol in different *Hevea* clones and in different localities.

Div.	*Hevea* clone	Age of planting in years	Area in ha	Tapping on virgin or renewed bark	Tapping system	Black thread damage in	
						1967 or earlier	in 1968 compared with previous year(s)
9	BD 5	20	192	first renewal	S/2.d/1.m/2	moderate	better
9	BD 5	25	210	second renewal	S/2.d/1.m/2	moderate	better
9	Tjir 1	24	160	first or second renewal	S/2.d/1.m/2	light	same
35	BD 5	12–14	644	virgin	S/2.d/1.15d/30	moderate	slightly better
35	Har 1	12–14	201	virgin	S/2.d/1.15d/30	almost none	same
42	BD 5	21	601	virgin (above old panel)	S/2.d/1.m/2	severe	same to worse
43	BD 5	28	689	second renewal	S/2.d/1.m/2	light to moderate	better

TABLE 13. Black thread control with captafol in some small-scale plantings (Div. 6, 11-year-old plantings of 2 ha each, tapped S/2.d/1.15d/30 on virgin bark).

Hevea clone	Black thread damage in	
	1967	1968
RRIM 501	moderate	none
RRIM 513	light	none
RRIM 526	moderate	light
RRIM 616	light	none
PB 86	very little	very little
AVROS 352	light	none
AVROS 1126	very little	very little

captafol as chances are remote that predisposing factors were less suitable.

The applications of captafol started too late in 1968 and in some plantings severe damage was done already when treatments commenced. This is one of the main reasons why unsatisfactory disease control was obtained on Div. 42; in later years, when captafol was applied timely, the disease became of minor importance in this division. Other reasons for better disease control in later years were:

a. Suitable colouring agents were added to the suspension, which allow for better supervision.
b. A concentrated suspension was first prepared at one central spot for the whole plantation, which suspension was after dilution with water in general

of better physical stability; in 1968, the suspensions were made separately at each division and without the aid of strong electric mixers.

It can be concluded that black thread can be controlled effectively with captafol in different *Hevea* clones and under different tapping systems, either tapped on virgin bark or on renewed bark.

5.5.8. *Side effects of captafol applications*

5.5.8.1. Physical properties of rubber

During application of captafol to the tapping panel, the tree lace is contaminated with captafol; the late drip production is also contaminated because of run-off of the suspension into the latex cup. The latex crop may also be contaminated. It was therefore deemed necessary to investigate whether this fungicide affects the physical properties of the rubber.

In early tests captafol was added to latex before coagulation. It was found that concentrations as low as 10 ppm in latex had quite a marked retarding effect on rate of cure. However, these results could not be reproduced in more extensive tests carried out later, and in which tests captafol was milled into dried rubber. Results are given in Table 14 and it was concluded that captafol quite definitely has a retarding effect on rate of cure, but that its effect cannot be detected at concentrations below 250 ppm in dried rubber.

Also were tested series of latex, cup lump and tree lace samples, which were collected in the field after normal captafol applications for black thread control. Particulars on these samples and on results are given below.

a. *Tests on latex.* All latex samples tested were from the first tapping after application of 1% captafol + 0.1% Ortho sticker in water. The samples were coagulated, milled, creped and cured in the usual way. Results of these tests –

TABLE 14. Physical properties of rubber, containing different amounts of captafol.

ppm captafol in dry rubber	Modulus 600%/p.s.i.	Tensile strength at break/p.s.i.
10,000	250	1,750
5,000	325	2,125
2,500	525	2,500
1,250	600	2,700
1,000	625	2,725
500	625	2,800
250	700	2,900
100	–	–
50	700	2,725
25	725	2,875
10	750	2,800
5	725	2,900
0	775	2,775

Firestone methods were followed for these tests; for principles see ANON., 1948, p. 65.

which are not reproduced here – indicated that the physical properties of the latex samples were the same as of the untreated control samples.

b. *Tests on cup lump and tree lace.* The quality of these offgrade rubbers was more extensively evaluated as contamination with captafol is much greater than with latex. Except for series V, all samples were collected in BD 5 plantings, tapped monthly periodic. The panels were treated with 1% captafol + 0.1% Ortho sticker in water. The samples of series I were from an area where captafol was applied early in the morning; the samples were collected about an hour later when tapping began. In all other cases application was in the afternoon and cup lump and tree lace were collected the following day before tapping. The rubber of untreated control trees was also collected and in a few cases of Treseal-treated trees. The tree lace samples were at first bark-washed and then milled and creped. More details on the samples are given below.

Series I: half a tapping task was treated with captafol and the other half left untreated. Cup lump was collected 4 times in November 1966 and the samples were processed and tested separately.

Series II: one treated task and one control task (approximately 450 trees/task). Tree lace and cup lump were collected 9 times in February/March 1967. The cup lump samples were processed and tested separately. Only one sample was made of the total tree lace crop per treatment as sample sizes of at least 10 kg were needed for bark-washing.

Series III: 12 to 13 tapping tasks per treatment. Cup lump and tree lace were collected twice in October 1967 and the samples were processed and tested separately.

Series IV: half a tapping task per treatment, replicated once in another task, which was tapped during the other months. Applications were made weekly from June to November 1967. Cup lump and tree lace were collected 26 times during these 6 months. The total crop was processed, giving one sample of cup lump and one sample of tree lace per treatment.

Series V: cup lump and tree lace of different *Hevea*-clones, collected in November/December 1968 after application of captafol.

The results of these tests on cup lump and tree lace are given in Table 15. The figures show – possibly with exception of the P.R.I. – that the physical properties of cup lump and tree lace were not or only slightly affected by captafol. The quality of tree lace was probably more strongly affected by Treseal in the few samples tested (Wallace plasticity and P.R.I.).

In practice, tree lace, cup lump and bucket lump are processed together. The specified minimum value of the P.R.I. is 35 for this offgrade rubber, which is well below the average figure for captafol contaminated rubber. In practice the rubber will contain less captafol than in the tested samples because applications are, in general, made once a week, so that contaminated tree lace and cup lump is mixed with the crop of days without captafol applications.

Based on some assumptions it is shown below that cup lump and tree lace must be contaminated with considerable amounts of captafol during application of the fungicide in the field. In series II, roughly 2.5 g cup lump and 2 g tree

TABLE 15. Physical properties of cup lump and tree lace samples, contaminated with captafol.

Series	Number of samples tested	Modulus 600%/p.s.i.		Tensile strength at break/p.s.i.		Wallace plasticity (100°C)		P.R.I. (140°C/ 30 min.)	
		cap.	con.	cap.	con.	cap.	con.	cap.	con.
cup lump									
I	4	1560	1310	3080	2840	62	63	73	72
II	9	1180	1230	2680	2890	41	41	53	75
III	2	1040	1080	2830	2780	52	52	75	72
IV	1	1225	1300	3000	3475	59	63	67	64
V	11	1220	1290	-	-	47	48	77	80
tree lace									
II	1	800	700	2380	2250	42	47	56	73
III	2	810	880	2700	2800	53	52	26	34
IV	1	600	650	2250	2275	53	53	54	54
V	6	850	800	-	-	51	50	53	58
		Tre.	con.	Tre.	con.	Tre.	con.	Tre.	con.
tree lace									
III	2	810	880	2490	2800	33	52	23	34
IV	1	580	650	2250	2275	37	53	56	54

cap. = captafol; con. = untreated control; Tre. = Treseal
For P.R.I. and Wallace plasticity tests see BATEMAN and SEKHAR (1965/'66).

lace were produced per tree per tapping. Generally, 2 to 3 ml of a 1% captafol suspension is applied per tree per application. Assume 0.5 to 1 ml adheres to the tree lace (brushed onto the tree lace or drained off from the treated portion of the panel) and 0.25 to 0.5 ml runs into the latex cup onto the late drip production. Under these conditions and assumptions the cup lump would contain 1,000 to 2,000 ppm captafol and the tree lace 2,500 to 5,000 ppm. However, as the quality of the tested samples was about normal and the critical level is probably around 250 ppm, the above figures indicate that most of the captafol must be washed out during processing of the rubber.

Far less captafol reaches the latex. Assume a daily crop of 100 ml latex per tree. In the merely hypothetical case that the total quantity of the suspension which runs off into the cup (0.25 to 0.5 ml) mixes with the latex, than the latex would contain 25 to 50 ppm captafol. However, only a fraction of this amount mixes with latex as the fungicide drips onto the cup lump, which is removed before the next tapping and practically all the captafol with it.

In bio-assays it was determined that samples of field latex, collected on the first tapping day after application of 1% captafol + 0.1% Ortho sticker in water, contained less than 10 ppm captafol (for technique see 5.2.1.). These tests were carried out in the dry season when latex production is low and no fungicide residue is lost because of rain, under which conditions the highest possible amounts of captafol mix with latex.

The conclusion can be drawn that chances are extremely remote that 1% captafol applications have adverse effects on the physical properties of the rubber. Also in commercial practice, ill effects have never been reported. Moreover, contamination of latex and cup lump can entirely be avoided when the cup is removed (or turned upside down) before application. This can be done when application is on rest days (in alternate daily tapping). In periodic tapping, application is normally within a few hours after tapping of the last trees and not all trees have ceased as yet producing at application time; in this case a portion of late drip production would be lost when cups are removed.

5.5.8.2. Latex production

I reported previously – and illustrated with some figures – that captafol applications have no direct effect on latex yield (SCHREURS, 1971). In Table 16, all available results are summarized, including these for the fungicide Treseal. The yields of captafol and Treseal treatments are expressed as a percentage of the untreated control; when the untreated control treatment was nonexistent, the yield of the Treseal treatment was made 100%.

The figures show that yields were generally above average in the captafol treatments, although differences were insignificant in most cases. Theoretically it is possible that the higher yields obtained are because of better black thread control, e.g. in Exp. 8. However, unless infections are very severe and bark below the tapping cut becomes diseased, chances are remote that the disease has such a direct effect on latex yield. In Exp. 42, captafol was applied in a high concentration during the dry months of December and January, thus in a period when the disease does hardly any damage. Normal yields were obtained under these conditions with captafol (with admixtures) and Treseal.

TABLE 16. Effect of fungicide applications on latex yield.

Exp. no.	Number of months	Dry rubber yields, expressed as a percentage of the treated or untreated control treatment		
		captafol	Treseal	Untreated control
8	5	107*	96	100
16	12	102	115	100
22	8½	113*	100	–
23	8½	111	100	–
35	18	102	100	–
42	2	102	99	100

Application of fungicides was weekly in these experiments. Applied was 1% captafol + 0.1% Ortho sticker, except for Exp. 42, in which case was used 2% captafol + 2% yellow iron oxide + 0.2% Ortho sticker + 0.02% Sterox.
* Yields were significantly higher compared with the other one or two treatments (exps. 8 and 22).

The conclusion can be drawn that captafol has definitely no direct adverse effect on latex yield. Also trees treated with Treseal, continued to produce normally.

5.5.8.3. Yield potential of treated renewing bark

In 1970, the now 4-year-old renewing bark which was treated with fungicides in 1966 (Exp. 8), was tapped again to test whether the 1966 treatments had any effect on the rubber producing capacity of the renewed bark (Exp. 39), viz. for three of the seven 1966 treatments. Details on the tapping history of this planting are given in Fig. 14; results are summarized in Table 17.

In Table 17, at first pretreatment yield data are given. As can be seen, yields were very much the same among treatments when Exp. 8 started (yields of April/May 1966). During this experiment, trees treated with captafol produced somewhat more and those with Treseal somewhat less than the untreated control

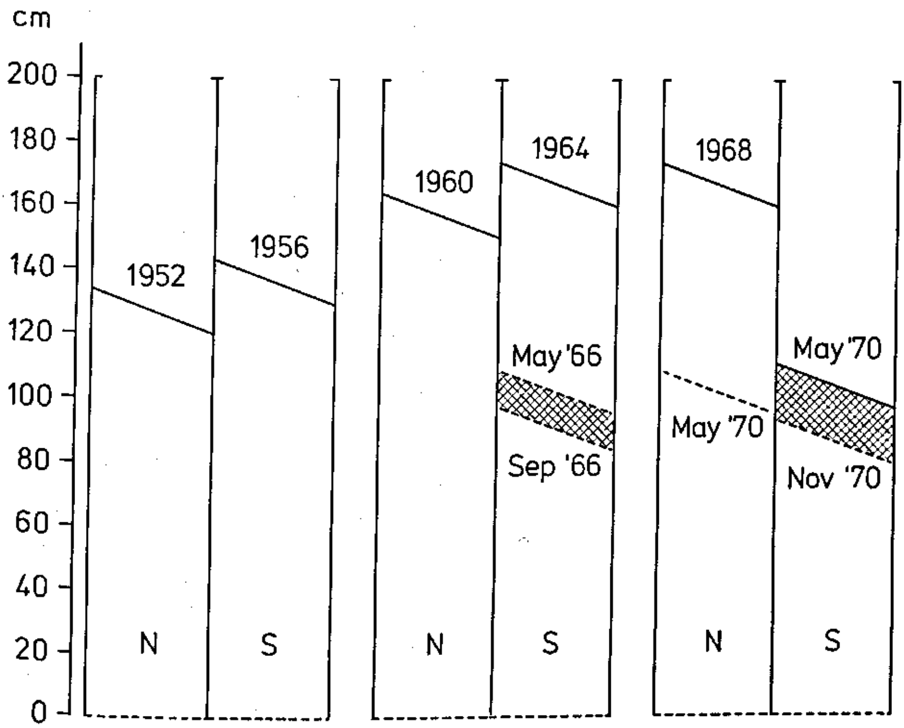


FIG. 14. Panel history of trees in Exp. 39. The trees were taken into tapping in 1952 and normal panel changes were made in 1956, 1960, 1964 and 1968. The position of the tapping cut, measured in cm above ground level, is indicated with a drawn line for the openings on north (N) and south (S) panel in different years. In Exp. 8 (in 1966) tapping was about half way down the south panel on first bark renewal (see shaded part). Mid May 1970, tapping on the north panel was discontinued (see dotted line) and a panel change made to the south panel at a height where the first fungicide applications were made in 1966. This 4-year-old bark (second renewal) was tapped through the entire portion treated in 1966.

TABLE 17. Yields obtained in 1966 (Exp. 8) and 1970 (Exp. 39).

Tapping period	Tapping on	Number of tappings	g dry rubber per tree and per tapping in different treatments		
			captafol	Treseal	untreated control
Apr/May '66	S-panel first renewal	21	37.3	38.1	38.1
May/Sep '66	S-panel first renewal	56–59	63.4	57.3	59.6
Apr/May '70	N-panel second renewal	21–22	20.0	19.7	19.0
May/Nov '70	S-panel second renewal	96–97	39.4	40.0	37.1
May '70		8–9	25.1	25.4	25.1
Jun '70		14	43.7	44.3	39.3
Jul '70		14	40.2	40.8	37.2
Aug '70		15	36.4	38.5	34.7
Sep '70		14	39.6	39.9	38.1
Oct '70		16	41.7	41.9	39.7
Nov '70		15	43.2	43.2	40.5
Number of trees per treatment in 1970			82	78	82

trees (May/Sep. 1966). In April/May 1970, when regular tapping was halfway down the north panel, yield data were collected to check whether these groups of trees were still of comparable yield level; the figures show that yields were low and practically the same. Mid May 1970, when Exp. 39 started, the trees were opened on the south panel at a height where the first fungicide applications were made in 1966. For regular black thread control, the trees of the 3 old treatments were treated with captafol in 1970.

The figures show that from May through November 1970 there was practically no difference in rubber yield between the trees of the 1966 captafol and Treseal treatments; the trees of the untreated control produced the least. These results indicate that captafol and Treseal have no adverse effect on the rubber producing capacity of treated renewing bark.

Observations were also made with respect to new and old black thread damage in the different treatments. The figures in Table 18 show the tendency to better disease control in 1970 when there was less old damage on the tapped portion (compare 1970 damage with 1966 damage for the 3 treatments). The figures in Table 19 give an impression of the degree of deformation of the 4-year-old renewing bark; its irregular renewal was the result of the infections by black thread in 1966. It is obvious that deformation was more severe when black thread incidence was greater in the past (compare data of Table 19 with corresponding 1966 damage figures in Table 18). However, the degree of deformation was apparently not great enough to have a marked effect on yield capacity of this bark (see Table 17).

TABLE 18. Black thread damage in Exp. 8 and 39.

1966 treatments	Pretreatment damage on panels of		1966 damage, evaluated in		1970 damage, evaluated in 1971
	1964	1965	1966	1970	
captafol	2.08	1.39	0.99	0.98	0.61
Treseal	2.11	1.46	1.93	2.20	0.68
untreated control	2.07	1.36	2.98	2.48	0.78

TABLE 19. Scars and swellings on 1966 panels, evaluated in 1970 (Exp. 8).

treatments 1966	% scars*	Degree of swelling**
captafol	9	0.26
Treseal	24	0.41
untreated control	30	0.52

* *% scars:* in 1970, practically all wounds, caused by 1966 black thread infections, had healed, leaving scars where healing tissues had met. The total length of these scars was measured parallel to the tapping cut and expressed as a percentage of the length of the tapping cut.
** *Degree of swelling:* the swellings are the result of abnormal cambium activity where wounds are healing or have healed (4.1.3.). The evaluated portion of the panel, tapped and affected in 1966, was also affected during the first tapping cycle in 1958. Evaluation criteria were from 0 (no such swellings) to 4 (a broad swollen up band around the entire panel in tapping).

5.6. RESIDUAL ACTION OF CAPTAFOL ON TAPPING PANEL

It is of interest to know how much captafol adheres to the bark after application, how persistent it is and whether it penetrates into the bark. Therefore samples of treated and untreated bark were collected and analysed in the laboratories of the Chevron Chemical Company in France. The method used was gas liquid chromatography (GLC method). The determined level of residue was corrected for the percentage of recovery, determined on untreated bark samples to which captafol was added in the laboratory.

The bark samples were of different sizes (range between samples: 52–561 cm^2 of renewing bark). Also, the samples received different captafol treatments (different concentrations and different frequency of application). When treatment is more frequent, the number of overlapping of treatments increases, resulting in more coatings with captafol, which is further explained under Series I. In view of the above, and to allow for direct comparison of the level of residue, the mg captafol determined were converted to sample sizes of 100 cm^2 bark and reduced to one coating with 1 % captafol suspension. The determined mg captafol per 100 cm^2 bark should be understood as found *on* or *in* that quantity of bark.

Series I: These samples were collected on September 9 to 15, 1970 and the extractions were made at least 2 weeks later in France. The samples were from 3 panels, treated with 1% captafol + 0.1% Ortho sticker in water. During January through March 1970 the bark was not treated. The first application was at the beginning of April, and thereafter weekly. From April through June 0.05% Panelred was added to the captafol suspension, and afterwards – upon receipt of yellow iron oxide – this colouring agent was added in 1% concentration + 0.01% Sterox. The renewing bark on the portions of the panel, tapped in different months, was cut out separately. Each sample amounted to 75 cm² bark, measuring 2.5 × 30 cm. Samples of 8 different tapping months were taken (January to August). The samples of tree no. 1 and 2 were allowed to dry in an air-conditioned room (23 °C, 65% relative humidity) for 5 days before shipping; the samples of tree no. 3 were packed at once after collection in airtight plastic bags and shipped the following day. Data on weight of bark samples (converted to 100 cm²) and on bark thickness are given in Table 20. Another sample of

TABLE 20. Miscellaneous data of bark samples, analysed for captafol content.

Portion tapped in month	Fresh weight in g/100 cm²			% loss of weight after 5 days in air-cond. room		Mean thickness of fresh bark in mm of tree 2
	tree 1	tree 2	tree 3	tree 1	tree 2	
Jan	44.1	50.3	53.3	46	49	6.2
Feb	39.1	47.7	49.7	48	52	6.0
Mar	36.8	48.4	50.3	49	53	5.5
Apr	35.6	49.2	46.4	47	53	5.5
May	38.1	44.4	43.2	49	53	5.0
Jun	33.5	36.9	39.1	52	54	4.6
Jul	32.8	25.2	32.4	55	55	4.0
Aug	20.3	24.1	25.6	59	59	2.7

6-month-old renewing bark was dried at 58 °C for 20 h, which reduced the weight of the living bark by 61% and of the cork by 32%, which figures indicate that the bark samples dried out rather effectively in the air-conditioned room (see Table 20). Each portion of the bark was usually treated 4 times because of overlap of captafol applications (4–5 applications per month to a band of 2–2.5 cm wide above the cut; bark consumption is about 2.5 cm per month). The March portion received some captafol during the applications made in April. The number of coatings on the August portion was estimated at 3 because all September applications had not been made when this sample was collected. Results of the analyses are given in Table 21.

The figures show that the captafol residue on the panel disappears with time because of decomposition or because particles drop off or are washed off by

TABLE 21. mg captafol per 100 cm² bark if treated once only with 1 % suspension (Series I).

Portion tapped in month of	Number of coatings	mg captafol		
		tree 1	tree 2	tree 3
Jan	0	–	–	–
Feb	0	0	0	0
Mar	1½	0	0.33	0.10
Apr	4	0.22	0.88	0.33
May	4	0.66	1.43	0.61
Jun	4	1.10	1.44	0.56
Jul	4	1.07	2.09	0.41
Aug	3	2.70	4.31	2.26

The samples were secondly renewing bark of 24-year-old BD 5 trees.

rain. Under the conditions of this trial, the level of residue amounted to 2.3–4.3 mg captafol per 100 cm² bark when treated recently with 1 % captafol suspension (August portion). However, at least 2 weeks had elapsed between collection of samples and extraction of captafol in France, during which period decomposition might have taken place; therefore, the actual level of residue might have been higher. The fact that the level of residue was the lowest in the samples of tree no. 3 – which samples were not dried before shipping but sent fresh – indicates that in this case decomposition of captafol probably had occurred. In view of these results, the bark samples sent at later dates were all allowed to dry for some days before shipping.

Series II: These samples were collected on February 17 to 20, 1971 and allowed to dry in an air-conditioned room till February 23, whereafter they were shipped. They were analysed several weeks later. The panels had been treated with 1 % captafol + 1 % yellow iron oxide + 0.1 % Ortho sticker + 0.01 % Sterox in water. Details on samples and results are given in Table 22. The cork was carefully separated from the living bark in a number of samples during collection in the field. It is known fairly accurately how much captafol was applied to the bark of Sample 16. Application was only once on these 4 trees and the sample was collected 1½ hour after application. The volume of the 1 % captafol suspension used was determined and the treated area measured. It was calculated that 11.3 mg captafol were applied to 100 cm² bark in this case.

The determined level of residue in Sample 16 amounted to 3.6 mg per 100 cm² bark. Less captafol than was applied must have adhered to the bark and/or decomposition must have taken place during the weeks between application and analysis. It is possible that a part of the applied captafol drained onto the tree lace during or shortly after application. The captafol content of the tree lace could not be determined, because the fungicide could not be extracted from the rubber. The figures also show that, with time, the quantity of captafol residue on the bark decreases (see samples 5–8 and 10–13). It is obvious that captafol does not penetrate into the living bark as the traces of captafol determined were of

TABLE 22. mg captafol per 100 cm² bark if treated once only with 1 % suspension (Series II).

Sample no.	Tree no.	Treatments	Portion tapped in month	cm² of sample of bark	Mean no. of coatings	Nature of sample bark	For 100 cm² bark: fresh weight in g	For 100 cm² bark: mg captafol reduced to 1 coating with 1 % suspension
1	4	untreated	Dec/Jan	77	0	cork	6.1	0.04
						living	25.8	0.02
2	5	2 % captafol; once a week	Dec/Jan	107	3.2	cork	4.2	2.15
						living	23.9	0.01
3	6	1 % captafol; once a week	Dec/Jan	87	3.2	cork	3.2	1.97
						living	18.1	0.02
4	7	untreated	Jan/Feb	85	0	cork	3.1	0.04
						living	14.0	0
5	7	1 % captafol; once a week	Nov	52	3	cork	4.8	2.78
						living	26.7	0.04
6	7	1 % captafol; once a week	Oct	58	4	total	31.6	2.97
7	7	1 % captafol; once a week	Sep	61	4	total	33.4	3.38
8	7	1 % captafol; once a week	Aug	58	4	total	36.2	1.02
9	8	untreated	Jan/Feb	169	0	total	22.7	0.12
10	8	1 % captafol; alternate daily	Nov	113	9	cork	4.6	1.98
						living	29.4	0.03
11	8	1 % captafol; alternate daily	Oct	113	15	total	36.6	2.08
12	8	1 % captafol; alternate daily	Sep	113	15	total	40.8	1.69
13	8	1 % captafol; alternate daily	Aug	113	15	total	35.6	0.93
14	9–10	untreated	Jan/Feb	214	0	total	27.8	0
15	11–13	1 % captafol; once a week	Dec/Jan	281	3.2	total	28.3	4.12
16	14–17	1 % captafol; once only	Jan/Feb	561	1	total	21.6	3.56

The words 'living' and 'total' (under heading 'nature of sample bark') refer to living bark and total bark (living + cork), respectively. The months of August to December are in 1970; the months of January and February in 1971. The sample nos. 1–3 are firstly renewing bark of 11-year-old Har 1 trees; nos. 4–13 are secondly renewing bark of 22-year-old BD 5 trees; nos. 14–16 are thirdly renewing bark of 26-year-old BD 5 trees.

the same order as for the untreated bark; evidently, contamination of samples with captafol was not entirely avoided during handling of samples. The level of residue varied between 2.0 and 4.1 mg for the rather recently treated samples (Dec/Jan/Feb. samples), which agrees very well with the results of the first series of samples.

5.7. Chemical and physical stability of captafol suspensions

Difolatan 80 WP gives a physically rather stable suspension in water. In tests – carried out by the manufacturer – with a 1.25% suspension of the wettable powder in water, 87% of the active ingredient captafol was still in suspension after 30 min. However, in the tropics, products are often not stored under dry and cool conditions and, accordingly, particles may aggregate to a certain extent during storage. In such instances, stable suspensions can nevertheless be obtained by first preparing a slurry so that aggregated particles fall apart.

It is of practical use to know for how long captafol suspensions can be stored with respect to chemical and physical stability. Thus, tests were carried out by the manufacturer with suspensions kept in different containers and after different storage times. Such tests were also done with suspensions containing different admixtures (colouring agents, stickers, detergent and latex stimulants). Latex stimulants (2,4-D and ethephon) were added to captafol suspensions to combine above-cut yield stimulation with black thread control (see Chapter 6 on yield stimulation). For information on why and how colouring agents, stickers and detergents were added to captafol suspensions, see 5.5.3. and 5.5.4.

To determine captafol content in suspensions, two methods were followed in the laboratories of Chevron Chemical Company in France:

a. *GLC-method:* samples were taken from captafol suspensions for analysis and oven-dried for 22 to 48 h at a temperature below 50°C. Next, captafol was dissolved in acetone with vigorous agitation. The acetone solutions were brought up to standard volume and clarified by centrifuging before analysis by GLC.

b. *Mycelium growth inhibition test:* carried out in 9 cm Petri dishes with 3 replicates for each fungus. Fungicides were mixed in the culture media and inoculation was made with 4 mm disks of the mycelium taken from cultures of *Botrytis cinerea* or *Rhizoctonia solani.* Mycelium growth was measured in mm at different days after inoculation.

Physical stability of captafol suspensions.

Results of these tests (Table 23) were evaluated 30 min. after the suspensions were poured into glass cylinders. The captafol content in analysed samples was determined by GLC.

The figures showed that Ortho sticker had no effect on the physical stability of Difolatan 80 WP suspensions in water. When the colouring agent yellow iron oxide was added, some Sterox was needed to obtain stable suspensions.

Results of other tests have shown that suspensions of normal physical stabili-

TABLE 23. Physical stability of captafol suspensions.

Mixture	Concentration	% of wettable powder in suspension	% of captafol in suspension
1. Difolatan 80 WP	1.25%	94.9	86.7
2. Difolatan 80 WP Ortho sticker	1.25% 0.10%	94.6	87.5
3. Difolatan 80 WP yellow iron oxide	1.25% 1.00%	flocculation	
4. Difolatan 80 WP yellow iron oxide Ortho sticker	1.25% 1.00%	flocculation	
5. Difolatan 80 WP yellow iron oxide Ortho sticker Sterox	1.25% 1.00% 0.10% 0.01%	as stable as Difolatan 80 WP alone (see 1)	
6. Difolatan 80 WP yellow iron oxide Ortho sticker Sterox	1.25% 1.00% 0.10% 0.00125%	poor suspension with fast sedimentation of yellow iron oxide	
7. Difolatan 80 WP yellow iron oxide Ortho sticker Sterox	25.0% 20.0% 2.0% 0.2%	stable suspension; sedimentation occurs after a few hours, but the deposit is easy to re-suspend	

Note that mixture No. 5 is the formulation most extensively tested in later field experiments; also in practice, it has given very satisfactory black thread control (5.5.4.). Mixture No. 7 is of the same composition as No. 5, however, 20 times more concentrated (the use of this concentrated suspension is mentioned under 5.5.7.).

ty are also obtained when 0.25% ethephon (Ethrel) is added to 1.25% Difolatan 80 WP in water. The isooctyl ester of 2,4-D increased physical stability of 1.25% Difolatan 80 WP suspensions, containing 1% yellow iron oxide, 0.1% Ortho sticker and 0.01% Sterox. Sterox was not needed when the ester was added in a concentration of 1% acid equivalent or higher; 0.005% Sterox was sufficient to obtain stable suspensions of the above mixture with 0.25% acid equivalent of the isooctyl ester of 2,4-D. Salts of the tested 2,4-D formulations (dimethylamine and sodium salts) had no noticeable effects on physical stability of Difolatan 80 WP suspensions. Difolatan-4-Flowable – a suspension type of formulation, containing 48% captafol – gave an unstable suspension in water when mixed with yellow iron oxide and addition of Sterox did not improve stability.

Chemical stability of captafol suspensions

Results of the bio-assay, given in Table 24, show that captafol maintained its effectiveness in the tested mixture for a storage period of 14 days in glass or aluminium containers. In concentrations of 50 and 100 ppm, mycelium growth was even more effectively inhibited in most cases with suspensions stored for

14 days than with a fresh suspension. It is not known whether the differences should be attributed to inaccuracies of the tests. Theoretically, it is possible that freshly made up suspensions are less effective because the maximum quantity of captafol has not yet dissolved (1.4 ppm in water).

Results of another experiment, in which possible degradation of captafol was determined by GLC, are given in Table 25. The suspensions were agitated once a day. Samples for analysis of 10 ml were taken after 1 hour, 7 days and 14 days.

TABLE 24. Mycelium growth inhibition test with captafol suspensions.

Storage of captafol suspension	ppm captafol added to culture media	Mean diameter of colony in mm for	
		Botrytis after 6 days	*Rhizoctonia* after 4 days
14 days in aluminium container	100	22.0	40.6
	50	25.0	41.6
	10	62.3	81.6
14 days in glass container	100	21.6	27.3
	50	30.6	57.3
	10	69.6	88.0
fresh suspension	100	36.0	42.6
	50	37.9	48.9
	10	69.0	86.5
check	0	90.0	90.0

The captafol suspension contained 12.5 g Difolatan 80 WP, 1 ml Ortho sticker, 1 ml Panelred, made up to 100 ml with water. Storage was at temperatures between 18° and 27°C, whereafter dilutions were made for mixing into culture media.

TABLE 25. Chemical stability of captafol suspensions.

Mixture	Number of days of storage	Percentage of recovered captafol			
		stored in glass		stored in aluminium	
		analysis on 10 ml from 100 ml mix.	analysis on 10 ml mix.	analysis on 10 ml from 100 ml mix.	analysis on 10 ml mix.
A	0	83	95	83	95
	7	88	95	77	94
	14	109	95	114	95
B	0	100	100	100	–
	7	–	98	96	–
	14	97	–	97	–

Mixture A contained 12.5 g Difolatan 80 WP, 1 ml Ortho sticker, 1 ml Panelred, made up to 100 ml with water; Mixture B: 12.5 g Difolatan 80 WP, 1 ml Ortho sticker, 10 g yellow iron oxide, made up to 100 ml with water. Storage was at temperatures between 20° and 30°C.

As it was rather difficult to obtain perfectly homogeneous samples from these rather concentrated suspensions, these mixtures were also prepared directly in quantities of 10 ml. The variation in test results between data for 10 ml samples, taken from 100 ml, should be attributed to these sampling inaccuracies. It can be concluded, based on the given figures, that the 2 mixtures are chemically stable, either kept in glass or in aluminium containers. It can safely be assumed – although not tested – that stainless steel containers can also be used.

The chemical stability of mixture No. 7 in Table 23 was also tested. Storage was at 25° to 30°C. After storage for 14 days, 96% of the captafol was recovered and 88% after 40 days in this concentrated suspension, determined by GLC. It can be concluded that captafol is stable for at least one month in such a mixture.

Chemical stability of captafol in mixtures with latex stimulants was also tested. From a mixture of 1.25% Difolatan 80 WP and 0.25% ethephon (Ethrel) in water, 97% of the captafol was recovered after storage for 8 days at 20° to 25°C. In mixtures of 1.25% Difolatan 80 WP (+ 0.1% Ortho sticker and Panel-red or yellow iron oxide) with 0.1–0.5% acid equivalent of the issooctylester of 2,4-D, there was no significant loss of captafol after storage for 4 days. These results indicate that the chemical stability of captafol is probably not affected by the tested latex stimulants.

6. YIELD STIMULATION

6.1. General information

The yield of the *Hevea* tree can be stimulated in different ways and with many different compounds. The main points are briefly discussed below.

It was found in the thirties that light scraping of the bark below the tapping cut resulted in increases in yield which were further enhanced by the application of palm oil to the scraped portion (BAPTIST, 1955). Copper sulphate increases yield when injected in the stem. Stimulation became of widespread acceptance after CHAPMAN (1951) reported the use of 2,4-dichlorophenoxyacetic acid (2,4-D) as an effective stimulant. Since that time, 2,4-D and the closely related compound 2,4,5,-T have been widely used as latex stimulants. More recent is the discovery of 2-chloroethylphosphonic acid (ethephon), which commercial formulation Ethrel can be applied in high concentrations without damaging the tree. With the growth regulators as 2,4-D and 2,4,5,-T, the treated bark becomes greatly proliferated in higher concentrations. Ethrel is now widely tested and used in practice. Promising results, obtained with ethephon, were first published by ABRAHAM, WYCHERLEY and PAKIANATHAN (1968). They also observed that the results were consistent with the view that all latex stimulants have the capacity to produce ethylene. Moreover it was concluded that the enhancement of latex flow may be expected by application of substances causing evolution in plant tissues of ethylene or other gases with similar physiological characteristics.

Stimulants are usually applied to a band of scraped bark immediately below the tapping cut (Method a) or on renewing bark immediately above the cut (Method b). A novel technique, which I developed, is to apply the stimulant (ethephon) to scraped portions of the vertical guide lines (Method c). RIBALLIER and D'AUZAC (1970) mentioned another method, which is application of the stimulant to scraped vertical strips of bark below the cut (4 bands of 2 × 25 cm or 1 × 50 cm), e.g. for the stimulant alpha-naphtylacetic acid (Method d). These 4 methods are pictured in the diagrams of Fig. 15. Further details on methods a, b and c are given under 6.2.1. Technique d is not further discussed as it is doubtful whether this method is of practical interest. Scraping of long, narrow strips is precise work and is difficult to realize on older bark of irregular renewal. Loss of crop because of latex flow over the edge of the cut at scraped parts is another risk.

There are 4 publications on the work done with latex stimulants on the Firestone Plantations in Liberia. Results obtained with 2,4-D were reported by LEVANDOWSKY (1960), ANLIKER and SCANLON (1965) and SCHREURS (1971). In the paper of ROSS and DINSMORE (1971), the first results with Ethrel are described. It is mentioned in these articles that 2,4-D is normally applied in palm oil for below-cut stimulation and in the petrolatum Treseal for above-cut stimulation.

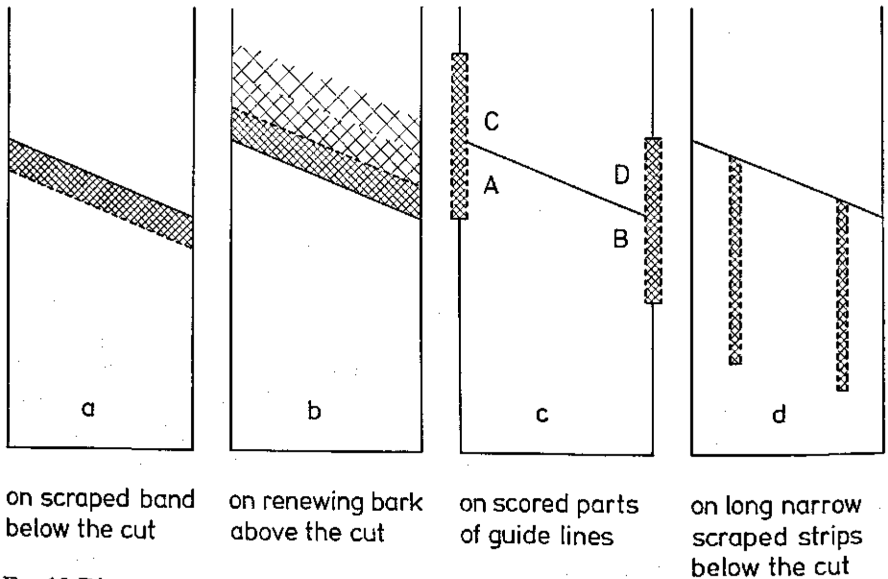


FIG. 15. Diagrams of different stimulation techniques.

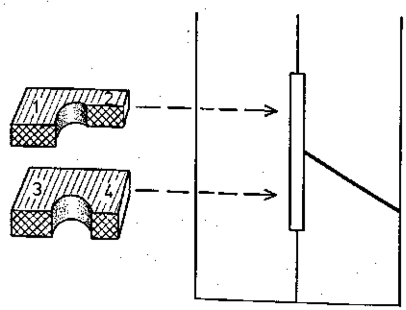


FIG. 16. Side view of tapping panel with scored parts of the left guide line. The bark sections show the difference in shape between the scored parts above and below the cut, caused by the right half of the scored part above the cut being located in young, renewing bark (2); in the other cases (1, 3 and 4), scoring was in virgin or renewed bark.

With Ethrel, very promising results were obtained in palm oil and in water, applied above and below the cut.

It was also reported that promising yield increase was obtained when 0.25–0.50% 2,4-D was added to captafol suspensions in water (SCHREURS, 1971). Complete results obtained with this method are summarized and discussed under 6.3.1. Later on, Ethrel also was tested in combination with captafol (ROSS and DINSMORE, 1971). More information on these experiments is given under 6.3.2. The new stimulation technique – application of Ethrel to scraped portions of the vertical guide lines –, briefly mentioned by ROSS and DINSMORE (1971), is described in detail under 6.2.1.; for results see 6.3.3.

This chapter on yield stimulation is concluded with considerations on profitability of stimulation (6.4.).

6.2. MATERIALS AND METHODS

6.2.1. *Stimulation methods*

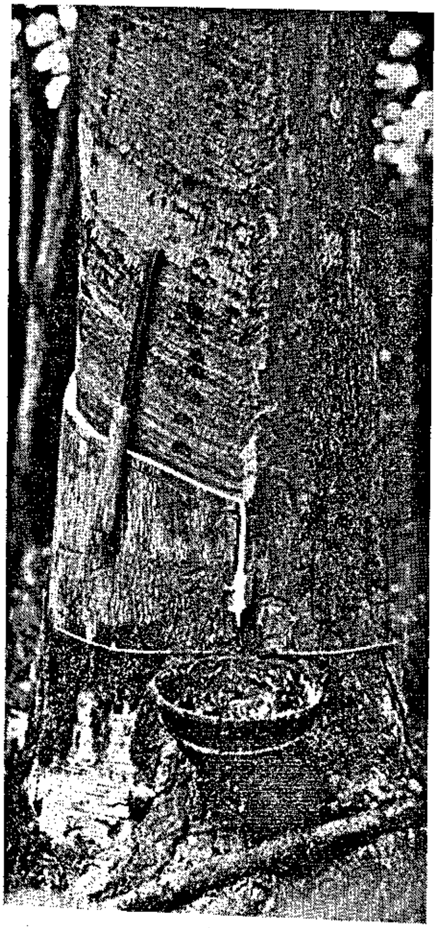
Details on standard and experimental stimulation techniques are given below. Advantages and disadvantages of methods are discussed. In tables, the different stimulation methods are abbreviated to B.C. (below-cut). A.C. (above-cut) and G.L. (guide lines).

a. *Below-cut stimulation.* A band of 1 or more inches wide is scraped and treated immediately below the cut. Cork and outer hard bast layers are scraped off to obtain better penetration of the stimulant into soft bast, which contains the latex vessels. Subsequent treatments are not made before the treated band is tapped off. With a bark consumption of 1 inch per month and a treated band of 2 inches wide, 6 applications can be made per year; however, in practice, stimulation is not the whole year round with this method and fewer applications are made. In Liberia, the butyl ester of 2,4-D is applied in palm oil in a concentration of 1–1.5% acid equivalent; Ethrel in a concentration of 1–10% ethephon, applied in palm oil or in water.

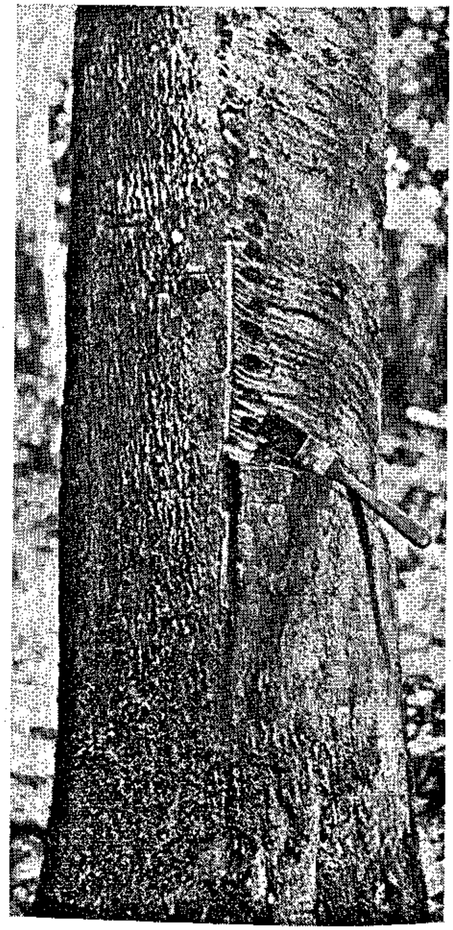
Below-cut stimulation results in exceptionally high yields immediately after application, but these decline rather rapidly. There are some disadvantages of this method: Firstly, thin and irregular bark cannot effectively be scraped and treated (extensive wounding and bleeding decreases yield response, and crop is lost because of latex flow over the edge of the tapping cut). Secondly, scraping is laborious and sometimes rather dangerous work (risk of eye-damage because of falling pieces of bark when scraping is on a high panel). Therefore, at old age when trees are tapped during their last cycle, stimulants are applied above the cut. Generally, trees are not stimulated before the first tapping cycle is completed because otherwise, e.g. girthing of the stem might be adversely affected with subsequent lower yield potential of the tree. Bark renewal is about normal on trees stimulated below the cut with 2,4-D, for which reason this method is used on the younger trees (when tapping is on first or second renewal).

b. *Above-cut stimulation.* Rather low concentrations of the stimulant (0.25–0.50% for 2,4-D) are applied weekly or less frequently over a band of approximately 0.5 inch wide immediately above the cut. Promising results were also obtained with Ethrel in a concentration of 1% ethephon. The stimulant 2,4-D is applied in Treseal and Ethrel in palm oil or water. An advantage of above-cut stimulation is the more favourable type of yield response, which does not have the high peaks in production obtained with below-cut stimulation (ANLIKER and

SCANLON, 1965). However, this method (above-cut application of 0.25–0.50% 2,4-D in Treseal) is not used when the renewing bark is to be tapped again, because of proliferation of the renewing bark; in addition, black thread is less effectively controlled with such mixtures than with Treseal alone (SCHREURS, 1971). The prospects for Ethrel are better in above-cut application as bark renewal seems to be normal. However, bark proliferation with 2,4-D is less severe when applied in aqueous media instead of Treseal; satisfactory disease control and important yield increases were obtained when 2,4-D was added to captafol suspensions in water (SCHREURS, 1971).



a



b

FIG. 17. Stimulation of the 2 guide lines on an 11-year-old seedling tree. Tapping was in virgin bark of first panel. The scale is 1:8.

a. Position D, scraped over 2 inches. The scraper is also shown. The black dots on the panel are coal tar marks, made by the tapper to indicate monthly bark consumption (1 inch per month).

b. Position A, scraped over 2 inches. Ethrel in palm oil was applied with the shown brush.

c. *Stimulation of guide lines.* Portions of the vertical guide lines – which are made to mark out the tapping panel – were lightly scraped and treated with Ethrel. The different treated parts were named positions A, B, C and D (Fig. 15c).

c1. *Scraping technique.* The channels were scored more deeply to remove dead bark layers. The left guide line is also named the back channel and the right guide line the front channel. Suitable scrapers were made of 15 mm wide files, used for sharpening of tapping knives. The end of the file was cut round, bent in a 60° angle and sharpened (Fig. 17a). Above the cut, one overlength half of the guide line is situated in young, renewing bark and the other half in virgin or renewed bark (Fig. 17a). A more detailed illustration of this is given in Fig. 16 for the other guide line, the back channel. Very light scraping of the part in renewing bark was sufficient to remove the very thin layer of dead tissues; after some practice, this could be done without much wounding.

c2. *Removal of wound rubber.* Wounding cannot always be avoided, especially not when scoring is above the cut or when the bark is thin and knobby. The wound rubber should be removed before application of the stimulant as a large part of the scraped channel (measuring 1.5–2.5 cm along the edge on section) may be covered with rubber. When the tree lace was thin (as in the *Hevea* clone Har 1), the wound rubber could be rubbed off with the finger or with a piece of cloth. On trees with thick tree lace (clone BD 5), the rubber could be pulled off at one go. Wound rubber is removed 1 or 2 days after scraping to allow for complete coagulation of the wound latex.

c3. *Positions and lengths of scraped and treated parts.* It is impractical to scrape and treat the front channel below the cut because the spout is positioned there. Therefore, in later experiments, position B was not tested. A treated back channel is shown in Fig. 17b (position A over 2 inches). Tested lengths and combinations of positions are given in Table 26.

TABLE 26. Tested guide line treatments with respect to length and combinations of positions.

Treated inches per position	Combinations of positions	Total inches treated per tree
2	A+C+D	6
	A+B+C+D	8
4	A	4
	A+B	8
	A+D	8
	C+D	8
	A+C+D	12
6	A	6
	C	6
	D	6
	A+C+D	18

c4. *Frequency of applications*. The frequency depends mainly on the length of the treated portions. When short parts are scored and treated, then more applications per year can be made without overlapping of treatments, compared with longer strips. Re-scoring and re-application on treated portions is possible, provided the first scoring was not very deep and bark is not very thin (Fig. 18). Scoring of the same portion for the third time within a few months will possibly cause too much wounding in general. The frequency of applications is worked out in Table 27 for the most promising combinations (positions A + D or C + D), which figures are based on continuous stimulation and on a bark consumption of 1 inch per month.

It is demonstrated in Fig. 19 that knobby and relatively thin bark can also successfully be scraped and treated as these portions show up clean and healthy. In half spiral tapping at 100% intensity, the scraped and treated bark has 4 to 5 years time to recover before tapping is again at that height (on the other panel) and the next stimulation cycle can begin.

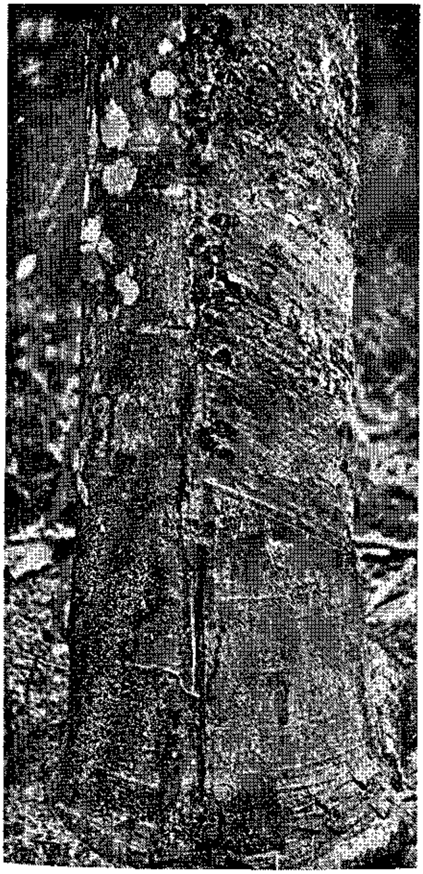
An advantage of this method is that the actual tapping panel is not treated, which probably lowers the risk of undesirable side-effects on renewing bark. Moreover, scraping of guide lines is easy, light work. Scraping costs and stimulant consumption are low.

6.2.2. *Experimental design*

It was previously mentioned (5.2.2.2.) that replicated tree plot design is the most effective way of testing the effect of applications of stimulants (or other treatments of the panel) on rubber yield. Layout is based on pretreatment yields or on girth of trees. Allocation of trees over the different treatments is in such a way that trees of different yield level (or of different girth classes) are equally represented in each of the treatments.

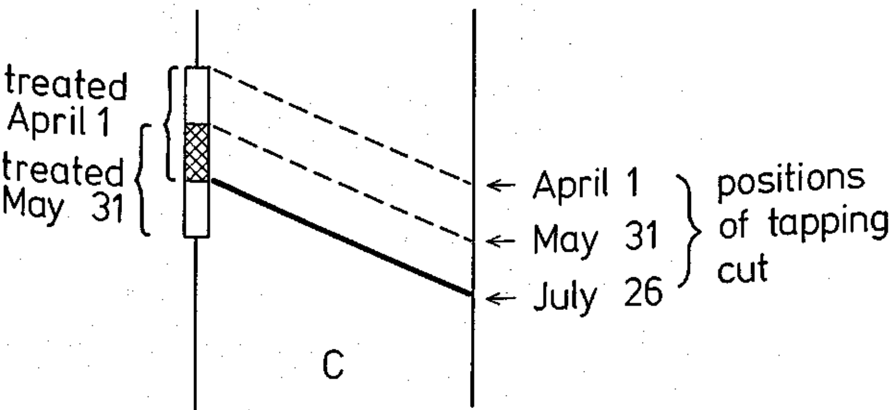
The layout of the experiments under review is based on pretreatment yields. The procedure was as follows. All trees of a suitable tapping task were marked on a map and yields were recorded for some time. Unsuitable trees were crossed out (with irregular tapping panel, irregular yields, wind damage, symptoms of root rot, et cetera). Next, tree numbers with corresponding yields were listed in ranked order of yield; trees with exceptional low or high yields were crossed out. Suppose 362 suitable trees remain in a tapping task of 450 trees. When there are 10 treatments, then 2 more trees must be left out to obtain a multiple of 10 trees.

FIG. 18. Re-stimulated back channel of an 11-year-old Har 1 tree. Tapping was in virgin bark of first panel. The scale is 1:8. On April 1, 1971, 5% ethephon in palm oil was applied to 4 scraped inches of this guide line below the cut. Two months later, when the cut had gone down 2 inches, 10% ethephon in palm oil was applied to 4 scraped inches below the cut (May 31). The photographs were taken July 26, about 4 months after the first stimulation. The appearance of the treated portion is shown in Fig. 18a. The living bark, exposed after removal of the dead corky layers, appeared to be healthy (Fig. 18b). It is shown in Fig. 18c which part was scored and treated twice.



a

b


treated
April 1
treated
May 31
April 1
May 31
July 26
positions
of tapping
cut

C

TABLE 27. Frequency of applications with and without overlapping of treatments for different lengths of treated portions of the guide lines.

Treated inches per position	Total inches treated per tree	Interval in months between applications	
		without overlapping of treatments	with one re-application on all treated portions
2	4	2	1
4	8	4	2
6	12	6	3

FIG. 19. Stimulated guide line in irregular bark of second renewal of a 26-year-old BD 5 tree. The scale is 1:8. The shown back channel was scored and stimulated over 4 inches below (position A) and 4 inches above the cut (position C). The photograph was taken 2 months later, and 6 inches of the treated portion are now located above the cut and 2 inches below the cut. During scoring of such irregular bark, wounding cannot entirely be avoided. Renewed bleeding may occur when wound rubber is removed before application of the stimulant, because damaged latex vessels are re-opened. In general, the second bleeding is not severe and the stimulant can be applied effectively. The picture gives evidence of this as the treated portion shows up clean.

In this instance, 36 trees are available for each treatment. In the described field trials, 10 trees per treatment was the lowest number (Exp. 11) and 86 trees the highest (Exp. 8); in the other experiments there were on the average 28 trees allocated to each treatment. The 10 treatment numbers were set out in the heading of a table. On the first horizontal (the first block), the tree number (and its yield) with the lowest yield was filled in under Treatment 1, the second lowest yielder under Treatment 2, and so on from left to right. On the second horizontal (the second block), this was continued from the right to the left, on the third again from the left to the right, and so on. In this way, the total pretreatment yields will differ very little between treatments, provided the number of horizontals (blocks) is not an odd number.

When the above precautions have been taken, it may be assumed that the groups of trees, selected for each treatment, are of the same yield potential. Moreover, the trees of each treatment will be fairly well distributed over the entire experimental field. This method was followed for exps 11, 16, 22 and 23. In a number of experiments, tapped alternate daily, the trees of each treatment were equally distributed over two farms (A and B), and in such a way that the various treatments were of the same yield level in each farm separately (exps 8, 35, 43, 45, 47). In some of the latest experiments (with all trees in one farm), the experimental field was first divided in 4 sections with about equal numbers of suitable trees, whereafter the trees were distributed over treatments for each section separately; this method ensures a still better distribution of trees over the experimental area for each treatment (exps 42, 44, 46).

The last thing to be done was to mark the trees in the field with different colours for the different treatments, to facilitate locating trees during application of treatments.

It may be added that better distribution of trees over the experimental field should reduce experimental error. When most trees of a treatment are centered in a small part of the area, then production of that particular treatment may be differently influenced by factors such as 1) time of tapping, 2) rainfall shortly before, during or shortly after tapping, 3) spreading of root rot centres, 4) wind damage. In brief, the replicated tree plot design reduces the chance that some treatments are more penalized than others by such factors. This can be demonstrated with figures on wind damage, collected in Exp. 46. During a storm, 11 experimental trees were lost in this trial with tree plot design. The figures below show that the losses were fairly well distributed over the 10 treatments, each treatment having 32 trees.

Treatment number:	1	2	3	4	5	6	7	8	9	10
Number of lost trees:	1	2	0	1	1	2	1	1	0	2

6.2.3. *Statistical analysis*

Statistical analysis of experimental yields and presentation of results are the same as for damage figures (see 5.2.2.3.). The plots (yields of each tree) were arranged in blocks according to pretreatment yields as described under 6.2.2.

Another possibility is, however, to use pretreatment girth figures instead of pretreatment yields, as yield and girth are positively correlated. Time can be saved when the layout is based on girth figures as collection of pretreatment yield figures is time-consuming and more laborious work. In Exp. 42 girth measurements were also taken. Below it is tested whether under the conditions of this experiment results are different with respect to significance of differences when blocking is by girth (Table 28).

The average girth of all experimental trees amounted to 78.13 cm. The range between treatment means amounted to 0.96. This low figure indicates that treatments were of comparable girth level. The results show that blocking by pretreatment yields gave more significant differences. It is obvious that, unless greater numbers of trees are used per treatment, relatively small differences in effectiveness between treatments cannot be traced when blocked by girth. Also it is doubtful whether, ultimately, time and labour is saved as this system requires a greater number of trees.

The closer correlation between later yields and preproduction – rather than between later yields and girth – can also be demonstrated with the figures of the untreated control trees.
Number of trees: 30.
Mean pretreatment girth: 78.17 cm (range between trees: 30 cm).
Mean pretreatment yield as g dry rubber per tree and per tapping: 63.7 (range between trees: 63).
Mean experimental yield as g dry rubber per tree and per tapping: 66.0 (range between trees: 76).

TABLE 28. Results of statistical analysis of experimental yields in Exp. 42, when based on blocking by pretreatment yields or by pretreatment girth.

Treatment no.	Total December + January yield as % of untreated control	Duncan test at 5% level	
		blocking by pretreatment yield	blocking by pretreatment girth
11	135		
10	114		
12	112		
4	110		
5	109		
8	109		
6	108		
3	104		
2	102		
7	100		
1	100		
9	99		
S_m = (for n_2 = 319)		2.392	3.823

We denote: x_1 = pretreatment girth; x_2 = pretreatment yield; x_3 = experimental (= later) yield. Correlation coefficients and *t* values are:

$r_{12} = 0.6090$ $t_{28} = 4.06^{++}$
$r_{13} = 0.5909$ $t_{28} = 3.87^{++}$
$r_{23} = 0.9252$ $t_{28} = 12.90^{++}$

All three correlations were highly significant according to the *t* test. However, the much greater value for r_{23}, compared with r_{13}, suggests that the experimental design measuring productions can better be based on preproduction than on girth. This becomes evident when the difference of the above mentioned correlation coefficients are subjected to a test described by CORSTEN (1970). The results of the 'likelihood ratio test' is a χ^2-value (d.f. = 1) of 28.65, which is much greater than the theoretical χ^2-value (d.f. = 1) of 3.84 (P = 0.05). Therefore the correlation between later yield and pretreatment yield is much higher than the correlation between latei yield and girth.

6.2.4. *Yield recording*

In experiments of replicated tree plot design the yield of each tree is determined. The latex yield of each tree was cup-coagulated and on the next tapping day the coagulum was strung on a wire, suspended from each tree. When the wires contain the yield of the required number of tapping days, the crop can be weighed either at the spot or be transported to a central weighing place, in which latter case each wire should be labelled with the tree number. The last method was followed in most experiments as weighings could be carried out at scheduled times (no interference of rain) and under better superivision. A disadvantage is that mistakes can be made in numbering the wires; the risk is reduced when numbers are checked before collection.

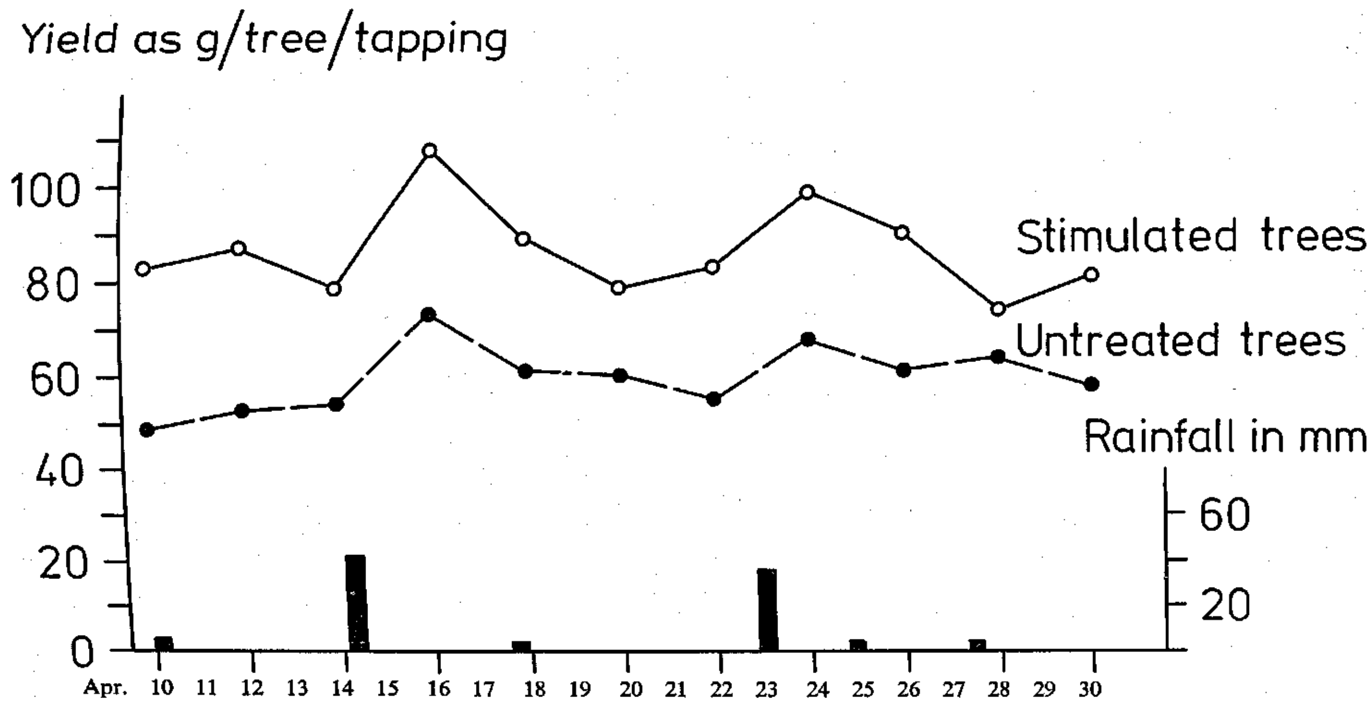
Usually, the wires with cup coagulum were stored at first in the dry house for several days to obtain superficially dry coagulum, which is easier and cleaner to handle. The superficially dried coagula still may contain a considerable amount of water, which varied generally between practically nothing and 25% of the total weight. The water content depends among other things on size of the coagulum; the bigger, the higher the water content. Accordingly, after weighing of individual tree productions, samples of different weight classes were weighed, creped, dried and weighed again to determine the water content. With these figures, the individual tree productions were corrected on water content to obtain dry rubber weights. Adjustment on water content is not essential during the recording period before treatment as high and low yielders are equally distributed over the treatments; however, during the experiment the mean water content of the coagulum in high yielding treatments can be much higher than in the untreated control, and so requires adjustment. Therefore, practically all yields weie expressed as dry rubber, given as g rubber per tree per tapping or as a percentage of the control treatment. It is also possible to carry the wires with coagulum from the field to the factory and to make crepes of all individual tree productions. However, processing of large numbers of samples is very time-consuming and another source of error.

In most experiments, yields were recorded before treatment during 3 months on the average (about 45 tappings). Because of lack of time, recording was only of 4 and 9 tappings, respectively, in exps 46 and 47. The time of recording amounted to 4–6 weeks in some recent large-scale Malayan trials with the stimulant Ethrel (ABRAHAM, 1970); in their small-scale trials recording was only for 2–4 weeks (7–14 tappings). However, longer periods are often preferred, e.g. 3 months. For how long this period should last depends also on the situation. This period can be of relatively short duration when tapping is of high quality (deep on all trees and without wounding), tapping panels are smooth and regular, and little crop is lost because of rain during the tapping operation.

The required time of recording of yields before treatment is independent of factors which influence the yield of all trees to about the same extent, such as seasonal and daily effects of the weather. The effect of the season on yield is shown in Fig. 1. Production is lowest in the middle of the dry season when trees are wintering and producing new canopies of leaves, average during the rainy season and highest towards the end of the rainy season and at the beginning of the dry season. Daily fluctuations in yield are shown in Fig. 20. In this particular case rainfall increased yield very markedly. The data were collected towards the end of a dry season with an exceptional low rainfall. The 2 distinct peaks in production of April 16 and 24 should be attributed to the rainfall of 1 or 2 days earlier; there was no relationship between temperature or relative humidity and yield in this instance.

A factor worth mentioning is the time of tapping. Trees tapped late produce below their normal yield level. Thus to give all trees an equal chance, trees which are tapped late one day should be tapped early the next day. Consequently, collected yield data are not representative for the normal yield level of the trees – and yields before and after treatment are not comparable – when the order of tapping of trees is not reversed at regular intervals. Therefore, in experiments and in commercial practice, the order of tapping trees is normally reversed after each tapping.

Sometimes data should be collected on the effect of incidental factors on yield, to allow for elimination of such effects in the experimental design. Such a situation arose when Exp. 35 was set up. Tapping was in virgin bark above the renewed bark of the old panel during the recording period before treatment. The tapping cuts were located at different heights and had passed the barrier between virgin and renewed bark in a number of cases. It is known that yields decline when the tapping cut approaches the junction of bark of different ages (PURSEGLOVE, 1968, p. 163). Therefore, the different tapping cut positions were equally allocated to each treatment. The yield data, collected before treatment in this experiment, are used here to show what effect the 'bark island' may have on production. For this purpose the trees were classified in groups according to position of the tapping cut (in renewed bark or 0–1, 1–2, ... up to 9–10 inches above the old panel). At least 10 trees fell in each category and 19 on the average. However, the average girth of trees varied widely between these categories. Classification of yield figures according to increasing girth revealed a practically



Apr.	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30		
	26	25	28	27	28	27	27	28	24	25	26	28	26	28	27	28	24	27	24	25	27	9:00	Temp. in °C.
	32	31	33	33	34	32	32	32	30	32	31	32	32	33	31	25	29	31	28	28	31	13:00	
	74	86	50	58	67	72	88	78	85	75	70	75	74	68	77	78	85	75	86	88	82	9:00	Rel. humidity
	44	52	41	37	42	56	52	52	52	50	54	52	52	45	52	92	65	52	60	68	59	13:00	

FIG. 20. Effect of rainfall in the dry season on rubber production. Yields are given for a number of consecutive tapping days in April 1971 (Exp. 46). Tapping was on alternate days, on April 10, 12, up to 30.

linear positive correlation between yield and girth in this clonal planting (see Fig. 21 A). A correction factor was calculated and yields were adjusted accordingly. The adjusted mean yield figures are plotted in Fig. 21 B. The graph shows that production had decreased by about 30% when the tapping cut reached the barrier, whereafter production went up again.

6.2.5. *Observations on bark renewal and wound healing*

These observations were confined to measurements of the thickness of renew-

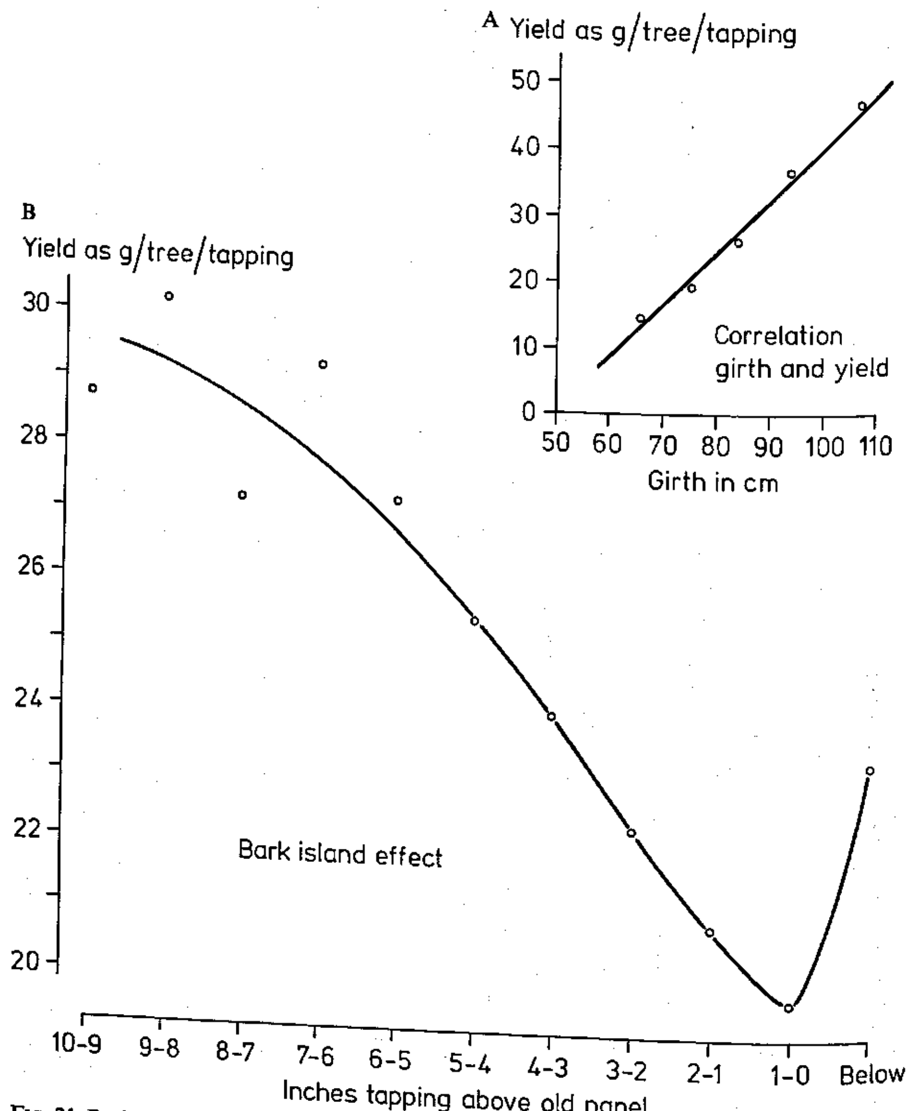


FIG. 21. Bark island effect on rubber production.

ing bark and to measurements of progress of wound healing tissues. The followed methods for measurement of the thickness of renewal were described in a previous article (SCHREURS, 1971); results were given of observations made on panels treated with fungicides (Treseal and captafol) and 2,4-D. At later dates, such observations were also made on panels treated with ethephon. The thickness of the renewing bark was measured with a LINDETEVES-STOKVIS 'Barkometer' (SHARP, 1937). Readings were taken to the nearest 0.1 mm. The thickness of the entire bark (living bark + cork) was measured and on 2 places for each panel, located 3 inches above the cut (Table 33).

The effect of fungicides and 2,4-D on rate of wound healing was studied in Exp. 35. (6.3.5.2.). Five trees of each treatment were selected for these observations. Tapping was on 2 trees on firstly renewed bark and on 3 trees in virgin bark. The 5 trees per treatment were chosen in such a way that mean girth, bark thickness and yield were of a comparable level for the different treatments. Circular pieces of renewing bark of 38 mm diameter were punched out just above the tapping cut at 2 spots per panel. The exposed wood and the bark (1.5 cm around the wounds) were treated with the products one or two days later when wound latex had coagulated and could be removed. More applications of products were made later on. Five months later, the diameter of the remaining exposed wood was measured in horizontal and vertical direction and mean progress of healing tissues calculated.

6.2.6. *Products used and their sources*

2,4-dichlorophenoxyacetic acid compounds (2,4-D)

- *butyl ester* (79% acid equiv.): Dow Chemical Co., Midland, USA
- *diethanolamine salt:* Super D Weedone weedkiller (13.7% acid equiv.); Amchem, Fort Washington, USA
- *dimethylamine salt* (72.5% acid equiv.): Uniroyal Chemical Div., Naugatuck, USA
- *isooctyl ester* (48% acid equiv.): Chevron Chemical Co., San Francisco, USA
- *sodium salt* (prepared from 2,4-D acid of unknown source)

ethephon (2-chloroethylphosphonic acid): Ethrel concentrate (Latex stimulant), containing 39.6% ethephon on a weight/weight basis: Amchem Fort Washington, USA

sodium 2,4-dichlorophenoxyethyl sulfate: Sesone 2,4-D weedkiller, containing 90% of the salt: Amchem, Fort Washington, USA

In text and tables, 2,4-D concentrations refer to the acid equivalent.

6.3. RESULTS OF FIELD EXPERIMENTS

6.3.1. *Yield stimulation above the cut with aqueous mixtures of 2,4-D and captafol*

Results obtained with such mixtures, applied weekly, are summarized in Table 29.

TABLE 29. Rubber yields with weekly above-cut application of 2,4-D in aqueous media, expressed as percentage of unstimulated yields.

2,4-D conc.	Admixtures	No. of experiment							
		11	16	22	23	35	42	43	44
sodium salt									
0.25%	0.5% Ortho sticker + captafol	–	–	139	131	–	–	–	–
0.25%	10% Santar A + captafol	126	–	–	–	–	–	–	–
0.25%	25% Mobilcer 67 + captafol	123	–	–	–	–	–	–	–
0.50%	captafol	–	–	133	151	–	–	–	–
diethanolamine salt									
0.25%	0.1% Ortho sticker	–	131	–	–	–	–	–	–
0.25%	0.1% Ortho sticker + captafol	–	124	–	–	–	–	–	–
0.25%	0.5% Ortho sticker + captafol	–	134	–	–	–	–	–	–
0.25%	10% Santar A + captafol	–	136	–	–	–	–	–	–
dimethylamine salt									
0.25%	0.1% Panelred	–	–	–	–	–	109	115	–
0.25%	0.1% Ortho sticker + captafol + yellow iron oxide + Sterox	–	–	–	–	–	108	129	116
0.25%	0.5% Ortho sticker + captafol	–	–	137	142	–	–	–	–
0.50%	captafol	–	–	149	152	–	–	–	–
0.50%	0.1% Ortho sticker + captafol	–	–	146	155	–	–	–	–
0.50%	1% XRD-24 + captafol	–	–	149	156	–	–	–	–
0.50%	10% XRD-24 + captafol	–	–	169	158	–	–	–	–
1.00%	0.1% Ortho sticker + captafol + yellow iron oxide	–	–	–	–	–	–	–	119
isooctyl ester									
0.10%	0.1% Ortho sticker + captafol + yellow iron oxide + Sterox	–	–	–	–	109	–	–	–
0.25%	0.1% Ortho sticker + captafol + yellow iron oxide + Sterox	–	–	–	–	115	109	111	–
0.50%	0.1% Ortho sticker + captafol	–	–	–	–	119	–	–	–
0.50%	0.1% Ortho sticker + captafol + yellow iron oxide	–	–	–	–	118	–	–	–
1.00%	0.1% Ortho sticker + captafol + yellow iron oxide	–	–	–	–	131	–	–	–
stimulated control treatment									
0.25% 2,4-D (butyl ester) in Treseal		132	144	157	171	164	114	147	123
Yield of unstimulated treatments as g dry rubber per tree and per tapping		59	44	42	44	26	66	44	49
Number of months of observation		4½	12	8½	8½	6	2	2	4

Yellow iron oxide and captafol were used in 1% concentration and Sterox in 0.005–0.01%. In exps 22 and 23, to all aqueous treatments 0.05% Panelred was added.

Without exception, treatments with 2,4-D salts yielded significantly higher than the untreated control treatment. On the average, yield increases amounted to 30% for 0.25% 2,4-D concentration and to 50% for 0.5% concentration in the *Hevea* clone BD 5 and under the conditions of these experiments. However, the stimulated control treatment (0.25% 2,4-D in Treseal) yielded still more than 2,4-D salts in aqueous media, and differences were significant in many cases.

For reasons not understood, the tested 2,4-D ester gave rather low yield increase in aqueous media when compared with 2,4-D salts; in concentrations up to 0.25% (2,4-D ester), differences with unstimulated yields were insignificant in the two experiments (clone BD 5). Ortho sticker, Santar A and captafol had no distinct effect on effectiveness of 2,4-D salts in aqueous media in the tested concentrations. However, higher yields were obtained when 10% XRD-24 was added, which product gives more bulk to the coating on the bark; in Exp. 22 the difference was significant when compared with the other aqueous 2,4-D treatments.

The above results show that important yield increase can be obtained with 2,4-D salts in aqueous media, with or without admixtures. The fungitoxic properties of such mixtures and effects on bark renewal will be discussed later (6.3.4. and 6.3.5.1.).

6.3.2. *Yield stimulation above the cut with aqueous mixtures of ethephon and captafol*

Results on the weekly above-cut application of ethephon are summarized in Table 30. Some of these results have already been published by Ross and Dinsmore (1971). The treatments are arranged in order of increasing ethephon consumption, roughly classified in groups of 0.5, 6, 30 and 70 g ethephon consumption per 100 trees per 2 months.

Yield increase was low with ethephon in concentrations up to 0.25%, being of the same level or lower than with 0.25% 2,4-D salts in aqueous mixtures (see also Table 29), and much lower than with 0.25% 2,4-D butyl ester in Treseal. Much more effective was below-cut stimulation with ethephon, which treatment consumed about the same amount of ethephon (6 g/100 trees/2 months).

However, high yield increase was obtained in the above-cut application of ethephon when a higher concentration was applied. In 1% concentration, yield increase was higher than for 0.25% 2,4-D in Treseal, and in Exp. 45 also higher than with below-cut application of 1% ethephon. In Exp. 45, the renewed bark was thin and knobby, under which conditions below-cut stimulation is not usually very effective. The highest yield increase was obtained with 2.5% ethephon, applied above the cut.

Addition of both propylene glycol and wax emulsion (Mobilcer Q) increased the responses of 1% ethephon applied in aqueous media above the cut during the first 2 months in exps 44 and 45 (see Appendix), the wax emulsion being probably somewhat more effective than propylene glycol. However, these admixtures had no significant effect over a longer period. The other admixtures (captafol and yellow iron oxide) have probably no effect at all on the effective-

TABLE 30. Rubber yields with weekly above cut application of ethephon in aqueous media, expressed as percentage of unstimulated yields.

ethephon conc.	Admixtures	No. of experiment			
		42	43	44	45
0.5 g ethephon/100 trees/2 months:					
0.025%	0.1% Ortho sticker + captafol + yellow iron oxide + Sterox	104	97	–	–
6 g ethephon/100 trees/2 months:					
0.25%	0.1% Panelred	100	117	–	–
0.25%	0.1% Ortho sticker + captafol + yellow iron oxide + Sterox	110	118	112	–
30 g ethephon/100 trees/2months:					
1.00%	0.1% Panelred	–	–	–	204
1.00%	0.1% Ortho sticker + captafol + yellow iron oxide + Sterox	–	–	130	213
1.00%	0.1% Ortho sticker + 10% glycol + captafol + yellow iron oxide + Sterox	–	–	131	234
1.00%	0.1% Ortho sticker + 20% Mobilcer Q + captafol + yellow iron oxide + Sterox	–	–	137	237
70 g ethephon/100 trees/2 months:					
2.50%	0.1% Panelred	–	–	–	290
stimulated control treatments:					
1% ethephon in water on 2" band below the cut (6 g ethephon/100 trees/2 months)		135	151	142	154
0.25% 2,4-D (butyl ester) in Treseal above the cut		114	147	123	179
Yield of unstimulated treatments as g dry rubber per tree and per tapping		66	44	49	22
Number of months of observation		2	2	4	4

Yellow iron oxide and captafol were used in 1% concentration and Sterox in 0.01%. Glycol was propylene glycol.

ness of ethephon.

Highest yield increase was obtained with 1% ethephon above the cut when applied in palm oil, although the difference with comparable aqueous applications was rather small in most instances. (see exps. 44 and 45 in Appendix).

The above results indicate that trees can be stimulated effectively above the cut with 1–2.5% ethephon in aqueous mixtures with captafol. The rather low responses in Exp. 44 could be because tapping was at low panel on virgin bark.

6.3.3. *Stimulation of guide lines with ethephon*

Results obtained with ethephon in palm oil, applied to scraped portions of guide lines, are summarized in Table 31. As undei 6.3.2., treatments are arranged in order of increasing ethephon consumption, roughly in categories of 3–4, 6–8, 10 and 15 g ethephon/100 trees/2 months.

TABLE 31. Rubber yields with application of ethephon in palm oil to scraped portions of guide lines, expressed as percentage of unstimulated yields.

ethephon conc.	Total inches treated per tree and positions of treated portions	No. of experiment			
		44	45	46	47
3–4 g ethephon/100 trees/2 months:					
5%	4″ (A)	–	–	109	–
5%	6″ (A)	–	–	–	113
5%	6″ (C)	–	–	–	119
5%	6″ (D)	–	–	–	116
2.5%	12″ (A,C,D)	–	–	–	137
6–8 g ethephon/100 trees/2 months:					
5%	8″ (A,B)	141	193	132	–
5%	8″ (A,D)	–	–	131	–
5%	8″ (C,D)	–	–	141	–
5%	8″ (A,B,C,D)	134	–	–	–
5%	12″ (A,C,D)	–	–	–	141
10 g ethephon/100 trees/2 months:					
5%	18″ (A,C,D)	131	245	–	161
15 g ethephon/100 trees/2 months:					
10%	12″ (A,C,D)	–	–	–	169
stimulated control treatments:					
1% ethephon in water on 2″ band below the cut (4–6 g ethephon/100 trees/2 months)		142	154	142	–
10% ethephon in palm oil on 2″ band below the cut (50 g ethephon/100 trees/2 months)		–	267	159	217
0.25% 2,4-D (butyl ester) in Treseal above the cut		123	179	127	–
Yield of unstimulated treatments as g dry rubber per tree and per tapping		49	22	55	46
Number of months of observation		2–4	2–4	2	2

The figures show that stimulation of guide lines with ethephon in palm oil is a very effective method, provided portions of each of the two guide lines are treated. Yield increases were higher than for above-cut application of 0.25% 2,4-D in Treseal and roughly of the same level when compared with 1% ethephon, applied below the cut. Treatment of *one* guide line only has little effect (compare position A with A,B and others in Exp. 46 and position A or C or D with A,C,D (2.5%) in Exp. 47).

Which part of each guide line is treated (above or below the cut) appeared to be of minor importance as differences in yield were insignificant (exps 46 and 47).

Results suggest that treatment of longer portions of guide lines (more than 4″ per guide line) may not result in much higher yields (compare 8, 12 and 18″ treated per tree).

The same high yield increases were obtained when already scraped and stimulated portions were re-scraped and stimulated for the second time; compare in Appendix for Exp. 44 results of Treatment 9b (second stimulation) with Treatment 9 (first stimulation), and for Exp. 45 results of Treatment 2 over the last 2 months (second stimulation) with the first 2 months (first stimulation).

Scoring of the guide lines, before application of the stimulant, is probably essential; compare in Appendix for Exp. 44 results of Treatment 9b (re-scraped) with Treatment 9a (not re-scraped).

Different concentrations of ethephon, applied to guide lines, were tested in one experiment only (Exp. 47). In this experiment, 10% ethephon in palm oil yielded significantly higher than 2.5% concentration; compare Treatment 7 (10%) with 4 (5%) and 6(2.5%).

In Exp. 46 (see Appendix), ethephon was also applied in aqueous media to guide lines. However, significantly higher yields were obtained when application was in palm oil (compare treatments 10 and 8).

Where guide line treatments were compared with below-cut stimulation with 10% ethephon in palm oil, the latter treatment yielded higher (difference insignificant in Exp. 45 and significant in exps 46 and 47); however, these higher yield responses were obtained at the expense of a much greater ethephon consumption.

The conclusion can be drawn that this new stimulation method merits further investigation since high yield response was obtained at low ethephon consumption. Other advantages of this method were described under 6.2.1.

6.3.4. *Effectiveness of fungicide/stimulant mixtures for black thread control*

Data on fungitoxic properties of captafol/2,4-D mixtures are summarized in Table 32. Results are compared with those of unstimulated control treatments (same mixtures without 2,4-D). Data on Treseal (with and without 2,4-D) are also given.

Without exception, more damage was done when 2,4-D (salt or ester) was added to the captafol suspension; however, except for Exp. 23, differences were insignificant. Also Treseal was less effective when mixed with 2,4-D and differences were significant in exps 11 and 35. In this case, the less effective disease control cannot be attributed to decomposition of the fungicide as this petroleum jelly has practically no fungitoxic properties; probably Treseal acts mainly as a mechanical barrier, preventing new infections. With 2,4-D in Treseal, the renewing bark becomes greatly proliferated with subsequent bleeding. Therefore, it is possible that the fungus penetrates through these unprotected wounds. Such bark is also of a very soft texture. Proliferation of renewing bark occurs also with 2,4-D in aqueous mixtures, although to a lesser extent. It was most severe in Exp. 23, and only in this experiment was the difference in effectiveness between captafol treatments (with and without 2,4-D) significant. Accordingly, proliferation and softer texture of stimulated renewing bark are possibly the main causes for less effective disease control. Faster decomposition of captafol, when 2,4-D is added to the suspension, is unlikely, especially with the ester of

TABLE 32. Black thread control with mixtures of captafol and 2,4-D in aqueous media.

2,4-D conc.	Other compounds in mixture	Black thread damage in Exp. No.:			
		11	16	23	35
sodium salt:					
0.25%	captafol + 10% Santar A	0.90	–	–	–
diethanolamine salt:					
0.25%	captafol + 0.1% Ortho sticker	–	1.37	–	–
dimethylamine salt:					
0.50%	captafol + 0.1% Ortho sticker	–	–	1.96	–
isooctylester:					
0.10%	captafol + 0.1% Ortho sticker + yellow iron oxide + Sterox	–	–	–	2.28
0.25%	captafol + 0.1% Ortho sticker + yellow iron oxide + Sterox	–	–	–	2.57
0.50%	captafol + 0.1% Ortho sticker	–	–	–	2.63
0.50%	captafol + 0.1% Ortho sticker + yellow iron oxide	–	–	–	2.63
1.00%	captafol + 0.1% Ortho sticker + yellow iron oxide	–	–	–	2.72
unstimulated control treatments:					
–	captafol + 0.1% Ortho sticker	–	1.15	0.59	2.00
–	captafol + 0.1% Ortho sticker + yellow iron oxide + Sterox	–	–	–	1.93
–	captafol + 10% Santar A	0.30	–	–	–
–	Treseal	1.80	0.94	2.59	2.94
stimulated control treatment:					
0.25% 2,4-D (butyl ester) in Treseal		3.85	1.33	2.20	4.46

Yellow iron oxide and captafol were used in 1% concentration and Sterox in 0.005–0.01%. In Exp. 23, to the aqueous treatments 0.05% Panelred was added.

2,4-D (personal communication of Chevron Chemical Company).

Although the above results indicate that less effective disease control might be obtained when 2,4-D is added to captafol suspensions, disease control was still rather effective in mixtures containing not more than 0.25% 2,4-D (SCHREURS, 1971). Mixtures of captafol and ethephon have not yet been tested on fungitoxic properties.

6.3.5. *Side effects of applications*

6.3.5.1. Bark renewal

The effects of 2,4-D, captafol and Treseal on bark renewal were described in a previous article (SCHREURS, 1971). The main results are reviewed below, supplemented with data on bark renewal of trees, stimulated with ethephon.

Treseal promotes bark renewal and captafol reduces growth initially; however, the thickness of the living bark became about normal after 2 years on panels treated with captafol. The conclusion was drawn that captafol has a temporarily retarding effect on the activity of the cork cambium, only initially reducing hard bast and cork formation. Evidence was obtained that soft bast renewal is about normal from the beginning, both on Treseal and captafol treated panels. It is to be expected that the initial differences in bark thickness between captafol and untreated panels will have disappeared when the bark has fully matured and is to be tapped again at the age of 8 to 10 years.

It was also reported that bark renewal is greatly stimulated with 2,4-D, i.e. hard bast and cork formation; soft bast renewal is about normal. With mixtures of 0.25% 2,4-D and 1% captafol in water about the same or slightly thicker renewal was obtained compared with untreated panels, because captafol reduced the increased growth obtained with 2,4-D (see data on bark thickness in Appendix for Exp. 16; data on Treseal and Antimucin are also given). With 2,4-D in Treseal, the renewing bark becomes greatly proliferated, which also occurs in aqueous 2,4-D treatments, although to a lesser extent (see data on deformation in Appendix for exps 22, 23 and 35). Latex is exuded through surface cracks in such bark (see data on bleeding in Appendix for Exp. 23). Proliferation with 2,4-D in aqueous media was greatest when stimulation of yield was most successful, that is in high 2,4-D concentration and in mixtures with stickers, which give more bulk to the coating of the bark. There was very little visibly proliferated renewal with 2,4-D in aqueous media in concentrations not exceeding 0.25%, although nevertheless important yield increase was obtained. The degree of proliferation differed widely between some experiments for the same treatments in the same *Hevea* clone, probably because of differences in girth of trees as there is a distinct negative correlation between girth and deformation. The cycle of bark renewal probably also has an influence on the proliferation. Two years after the applications dead cork layers began to slough off. The bark under the proliferated cork was more knobby than on unstimulated panels. A review of available literature showed that it is still uncertain whether the renewed bark of trees stimulated with 2,4-D above the cut will produce a normal yield for another whole tapping cycle. On its own, the thicker renewal is an advantage on older trees with thin bark as it facilitates tapping.

In contrast to 2,4-D, the new stimulant ethephon has probably no marked effect on bark renewal. When applied in high concentration above the cut, there was no proliferation nor bleeding. In Exp. 45 it was checked for a number of ethephon treatments whether the thickness of the renewing bark is also normal. The thickness of 3-month-old renewing bark was measured in 7 treatments and on 12–14 trees per treatment, viz. on July 26, 1971 at 3 inches above the tapping cut at 2 spots per panel. The average girth of these trees was 83.1 cm (range between treatment means: 0.7). The results of these measurements are given in Table 33. Data on the yields over a 4-month-period of these groups of trees are included (yield of untreated control amounted to 22.3 g dry rubber per tree and per tapping).

TABLE 33. Thickness of 3-month-old renewing bark in different ethephon treatments in Exp. 45. The corresponding rubber yields are given as percentage of the untreated control.

Treatments	mean bark thickness in mm	Duncan test at 5% level	rubber yield
A.C. – 1% ethephon in palm oil	5.63		265
Untreated control	4.76		100
A.C. – 2.5% ethephon + 0.1% Panelred	4.65		301
A.C. – 1% ethephon + 0.1% Panelred	4.64		198
G.L. – 2 × 4″ (A,B) – 5% ethephon in palm oil	4.57		191
B.C. – 2″ band – 1% ethephon + 0.2% Panelred	4.51		154
A.C. – 1% ethephon + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide + 0.01% Sterox	4.31		194
S_m = (for $n_2 = 78$)	0.1153		9.266

The treatments were applied in water when not in palm oil.

The significantly thicker bark renewal in the above-cut treatment with 1% ethephon in palm oil should be attributed to the growth stimulating effect of palm oil, as 1% and 2.5% ethephon in water gave a normal bark renewal. The only treatment which produced a significantly thinner bark renewal than the untreated control was that which contained captafol, to which fungicide the reduced growth should be attributed. All other differences were insignificant, indicating that ethephon has little or no effect on the thickness of the renewing bark. However, it is still not known whether bark renewal will continue to be normal when trees are stimulated with high concentration of ethephon for a longer period, as ultimate exhaustion of the tree – because of excessively high withdrawal of latex – may have adverse effects.

6.3.5.2. Healing of wounds

In section 6.3.5.1. it was mentioned that captafol slows down bark renewal initially and that 2,4-D promotes bark renewal. It was therefore deemed necessary to investigate whether these chemicals might influence healing of wounds (tapping wounds or black thread wounds).

In July 1969, circular pieces of renewing bark were punched out in Exp. 35 and products were applied as was described under 6.2.5. The special application of treatments to the wounds was repeated one week later. In addition, the panels were treated weekly with these products throughout the year for black thread control and yield stimulation.

The mean values, given in Table 34, are based on fewer than 20 measurements per treatment (5 trees, 2 wounds per tree, 2 measurements per wound) because of irregular healing. Along the edge of wounds, irregular healing was sometimes caused by black thread infections. In some instances, new bark and wood was formed on isolated spots in wounds; in such cases the cambium was obviously not entirely removed or destroyed when the piece of bark was cut out. In Treatment 2 healing was too irregular to be measured. Consequently, because of the many missing data, results are not very reliable.

The figures show that captafol has probably no adverse effect on healing of wounds as rate of growth of healing tissue was about the same as in the Treseal treatment.

There is a distinct tendency towards faster wound healing when 2,4-D is added to the captafol suspension. This might explain why in treatments with captafol + 2,4-D, black thread damage was evaluated as less severe in later observations (compare June 1970 evaluations with December 1969 evaluations in Exp. 35 for captafol treatments with and without 2,4-D). Therefore, although captafol in mixtures with 2,4-D may give less satisfactory disease control initially (see also 6.3.4.), the faster wound healing may partly compensate for it.

The slow wound healing in the Antimucin treatment was probably mainly caused by black thread; 7 out of 10 wounds became infected in this treatment, which was 3 wounds at the most in other treatments. Although the exposed wood between healthy looking healing tissue was measured, overgrown infections may have inhibited normal growth or diseased bark elswhere around the circle might have retarded growth of the remaining healthy tissue.

Normal radial wound healing amounted to about 1.5 mm per month in this trial, thus wounds closed at a rate of about 3 mm per month. Actually, wounds healed faster as progress of healing tissue in horizontal direction was about 30% faster than vertically. In the *Hevea* clone Har 1, such wounds closed even 60% faster in horizontal direction.

TABLE 34. Rate of growth of healing tissue in various treatments in Exp. 35 during a 5-month-period.

Treatments	Mean monthly radial growth in mm
8. 0.5% 2,4-D + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide	1.84
9. 1% 2,4-D + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide	1.74
4. 0.5% 2,4-D + 1% captafol + 0.1% Ortho sticker	1.62
6. 0.1% 2,4-D + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide + 0.01% Sterox	1.56
7. 0.25% 2,4-D + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide + 0.005% Sterox	1.54
1. Treseal	1.48
3. 1% captafol + 0.1% Ortho sticker	1.44
5. 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide + 0.01% Sterox	1.44
10. 1% Antimucin + 5% Mobilcer Q + 0.05% Panelred	0.98

The issooctyl ester of 2,4-D was used; all treatments were in water, except for Treseal.

6.4. Effectiveness and profitability of different stimulation methods with Ethrel

6.4.1. *Ethrel requirements*

To evaluate the relative effectiveness of stimulation methods it is of importance to know how much of the stimulant was applied.

The quantities of mixtures used in different treatments were determined in exps 42–47, and are given as grams of mixture per 10 trees per 2 months (see treatments with corresponding quantities in the Appendix). These figures are based on one application per 2 months for below-cut (2″ band) and guide line treatments, and on 9 applications per 2 months for above-cut treatments. Tapping was at half spiral cuts and the average girth of trees at tapping height varied from 78–84 cm between experiments.

An average consumption of mixtures was calculated from the above mentioned figures for different stimulation methods. The original figures show a large variation in use of mixtures for comparable treatments, the main reason probably being that applications were made by different people. Ethrel and admixtures had no substantial effect on the quantity of liquid used. However, the figures show a tendency towards the use of less mixture in palm oil than in aqueous media.

Data on average consumption of mixtures are given in Table 35 for a number of tested treatments (or worthwhile to be tested). The consumption is expressed in grams of mixture per 100 trees per 2 months. The mean grams of mixture for

Table 35. Mean use of mixtures for different stimulation methods.

Treatments	g mixture used per 100 trees per 2 months	Concentration of ethephon (on w/w basis)	ml Ethrel in mixture	g palm oil in mixture
A.C.	2,300	0.25%	12	2,286
		1%	48	2,242
B.C. – 2″ band	530	1%	11	517
		10%	111	396
G.L. – 4″ per tree	78	5%	8	68
		10%	16	58
G.L. – 6″ per tree	96	5%	10	84
		10%	20	72
G.L. – 8″ per tree	115	5%	12	101
		10%	24	86
G.L. – 12″ per tree	153	5%	16	134
		10%	32	114
G.L. – 18″ per tree	209	5%	22	183
		10%	44	156

The above figures are based on Amchem Ethrel concentrate, which contains 47.94% ethephon on a weight/volume basis. The specific gravity of this Ethrel formulation is 1.21; it amounted to 0.907 for palm oil at 32°C.

different guide line treatments were derived from a regression equation (length of treated guide lines against quantities of mixture used) to obtain mean values which better agree with each other.

6.4.2. *Effectiveness*

In Table 36 the different methods are listed in order of high to lowest Ethrel consumption; also given are the corresponding yield increases obtained in the different experiments. All treatments were in palm oil, except for 1 % ethephon applied below the cut, which was in water.

TABLE 36. Rubber yield, obtained with different stimulation methods in various experiments and expressed as percentage of unstimulated control treatment, compared with Ethrel consumption.

Treatments	ethephon conc.	ml Ethrel per 100 trees per 2 months	No. of experiment			
			44	45	46	47
B.C. – 2″ band	10%	111	–	267	159	217
A.C. –	1%	48	139	268	–	–
G.L. – 3 × 4″ (12″)	10%	32	–	–	–	169
G.L. – 3 × 6″ (18″)	5%	22	131	245	–	161
G.L. – 3 × 4″ (12″)	5%	16	–	–	–	141
G.L. – 2 × 4″ (8″)	5%	12	141	193	135	–
B.C. – 2″ band	1%	11	142	154	142	–
G.L. – 3 × 2″ (6″)	5%	10	–	–	–	151
G.L. – 3 × 4″ (12″)	2.5%	8	–	–	–	137

The above yields are over periods of 1½ to 4 months. Yields of comparable treatments were averaged.

The general impression obtained from the presented figures is that the guide line treatments are of about the same effectiveness as below-cut stimulation with regard to Ethrel consumption and at least as effective as above-cut stimulation.

6.4.3. *Costs and profitability*

As Ethrel is a much more expensive product than the conventional stimulants like 2,4-D and 2,4,5,-T and, in addition, is often used in much higher concentration, it is of importance to know what yield responses are required to make up for stimulation costs.

Very roughly, the extra crop required depends mainly on stimulation costs, the rubber price and processing costs, for plantings producing above marginal cost level. It is assumed that there are no substantial changes in other costs, such as overhead and tapper coverage, provided the tapping system is not altered under stimulation. Possible extra costs for collection and transportation of additional latex are also ignored. Within the above limits the extra crop required to make up for stimulation costs equals:

$$\frac{\text{stimulation costs}}{(\text{rubber price} - \text{processing costs})}$$

It should be realized that this simple formula cannot be used for accurate calculations; it merely will give some idea of the level of yield response required to make up for stimulation costs. For detailed information on profitability calculations is referred to NG ENG KOK, NG CHOONG SOOI and LEE CHEW KANG (1969).

a. *Stimulation costs*

Cost figures are based on an Ethrel price of US $ 80.00 per US gallon (is 2.11 dollar cents per ml) and a palm oil price of US $1.28 per US gallon (is 37.3 dollar cents per kg.) The given data (see Table 37) apply to continuous stimulation, thus to 52 applications per year for weekly above-cut stimulation and to 6 applications per year for below-cut and guide line treatments. Scraping and application costs were estimated at US $1.68 per acre per year for below cut stimulation and at US $1.26 for guide lines. Furthermore, a rubber stand of 100 trees per acre is assumed. Little costs are ignored, e.g. for brushes and containers. It depends on local conditions whether costs for application of stimulants above the cut have to be taken into account. For below-cut stimulation, the ethephon concentration used in commercial practice is within the range given in Table 36 (1–10%). A concentration of 1% is possibly most promising for weekly above-cut stimulation; for stimulation of guide lines, concentrations of 5–10% deserve further testing. Expenditures for palm oil are very high for above-cut stimulation; therefore this treatment becomes considerably cheaper for application of Ethrel in water.

TABLE 37. Costs of stimulation with Ethrel per acre and per year.

Treatments	ethephon conc.	Quantities		Costs in US $			
		ml Ethrel	kg palm oil	Ethrel	palm oil	scraping and application	total
A.C.	0.25%	72	13.7	1.52	5.11	–	6.63
	1%	288	13.5	6.08	5.04	–	11.12
B.C. – 2″ band	1%	66	3.1	1.39	1.16	1.68	4.23
	10%	666	2.4	14.05	0.90	1.68	16.63
G.L. – 2 × 4″ (8″)	5%	72	0.6	1.52	0.22	1.26	3.00
	10%	144	0.5	3.04	0.19	1.26	4.49

b. *Profitability calculations*

The costs of the cheapest and the most expensive stimulation method varied between US $3.00 and US $16.63 per acre per year under the described conditions. For further calculations round figures from US $3 to 15 are used. The minimum yield increase needed to compensate for stimulation costs can now be calculated with the given formula. The rubber price is here assumed to be US $0.15 per pound dry rubber and the processing costs US $0.03 per pound.

The results of these calculations are given in Table 38. The minimum extra crop needed is also expressed as percent over unstimulated yields at different levels. The figures show that relatively small increases in yield already compensate for the costs of rather expensive stimulation methods. A high profit is made on crop produced in excess of the listed minimum extra pounds; main costs for such rubber are for processing only under the described conditions.

TABLE 38. Minimum extra crop (in pounds/acre/year and as percent over unstimulated yield of different levels) needed to make more profit at stimulation costs of US $ 3.00 up to $ 15.00/acre/year.

	stimulation costs per acre and per year:				
	$ 3.00	$ 6.00	$ 9.00	$ 12.00	$ 15.00
	Extra crop needed in lbs/acre/year:				
	25	50	75	100	125
Unstimulated yield in lbs/acre/year	Extra crop needed as percent over unstimulated yield:				
800	3	6	9	13	16
1,000	3	5	8	10	13
1,200	2	4	6	8	10
1,400	2	4	5	7	9
1,600	2	3	5	6	8
1,800	1	3	4	6	7

7. DISCUSSION

Black thread disease

It was shown in Fig. 2 that black thread wounds were of nearly identical shape on a tapping panel during 3 consecutive rainy seasons. This phenomenon was often observed. Experimental results indicated that the exposed surface of old wounds is probably not a source of infection for the bark below, tapped during the following rainy season (Section 4.2.8.). However, there remains the hypothetical possibility that the fungus can travel internally through the portion tapped in the dry season (and without affecting it) towards the next rainy season panel. There are other possible explanations for the similarity in shape of wounds: the chances of successful infection and further development of the fungus could be greater on a particular side of the panel, because of a more suitable microclimate (e.g. less direct sunshine; prolonged flow of drainage water from above) or because of greater susceptibility of that bark (physiological differences between portions of bark).

The impression was obtained that when tapping is on renewed bark, the disease does more damage when previously affected portions – whose wounds had healed – are tapped again. Necrosis symptoms in the wood, studied in sections through stems with a severe black thread history, suggest that the bark on such portions is more liable to infection because more tapping wounds are made on irregular bark or because such bark is infected from innerlying necrotic wood. However, *Phytophthora* could not be isolated from the lesions in the wood (4.1.3.). It is believed in Liberia that tapping wounds increase black thread damage.

There is little doubt that the tapper is an important factor in the spread of the disease (4.2.6.). BELGRAVE and DE LA MARE NORRIS had already reported in 1917 that the path of spread of the disease often coincides with the path of the tapper. They thought that the disease was probably spread by the tapper's hands, rather than by the tapping knifs.

Other sources of infection, mentioned in literature, are the soil, *Hevea* leaves and pods. Which sources are most important probably depends on local conditions. It was proved that there is a close positive correlation between new and old damage on the same tree, although the nature of this correlation is still not very well understood (4.2.4.). Therefore, it seems logical to take trees with a severe black thread history out of tapping for the entire rainy season to prevent build up of new infections (4.2.7.).

Control of black thread

In field trials, the fungicide captafol controlled black thread more effectively than other fungicides used for control of this disease, such as the organic mercury compound Antimucin (active ingredient: phenyl mercury acetate) (5.4. and 5.5.). The fungicide captafol is non-hazardous to the operator (WASTIE, 1969). In bio-assays, however, Antimucin was more fungitoxic than captafol (5.3.).

According to RIGGENBACH (1959), Antimucin has cellulose-fixing properties which prevent it from being washed off by rain. This observation might explain why this product should be applied frequently (after each tapping) as its action is obviously limited to the treated strip of bark. There are reasons to believe that captafol gives some protection to the untreated strip of bark below the treated portion (5.5.5.). The following information, received from the manufacturer of Difolatan in personal communications, sheds some light on the mode of action of this persistent chemical.

'Solubility of captafol in water is very low (about 1.4 ppm). The dissolved captafol has a reasonable stability and its rate of hydrolysis is a function of pH and temperature (disintegration is faster in alkaline environment). In bioassays, spores of fungi were effectively killed with the low concentration of dissolved captafol in water. It is therefore believed that the dissolved captafol in the waterfilm of wet panels can reach an effective concentration which permits contact of fungus and the material. The insolubility of captafol permits a continuous source of captafol for dissolution. Moreover, experimental results seem to definitely indicate an ability for Difolatan to redistribute under wet conditions and at sufficiently high concentration.'

In view of the above it is not surprising that addition of bulky stickers (such as high concentrations of wax emulsions) might decrease effectiveness, as dissolution of captafol in the water phase and redistribution are probably reduced (5.5.3.). The above information might also help to explain why the untreated strip of bark, tapped after a last application, stays relatively healthy for a whole week (whereafter this strip is also treated in weekly application); it is probably the dissolved captafol, originating from above-lying portions, that gives protection (5.5.5.). Considering the above facts and theories, it might be worth trying to apply higher concentrations of captafol (e.g. 2% or even more) less frequently (e.g. twice a month).

Yield stimulation

Stimulation experiments were initiated to test mixtures of stimulants (2,4-D and ethephon) with captafol in aqueous media, thus to combine above-cut stimulation with black thread control. Later, ethephon was also tested on scraped portions of the vertical guide lines. In general, these experiments were of short duration and so described methods should be tested more extensively and for longer periods to check upon their practical value.

In a number of these experiments, below-cut stimulated trees – scraped and treated over a 2-inch-wide band – were used as stimulated control treatment (exps 42–47). For easy comparison of effectiveness of treatments, data given in Section 6.4. were based on continuous stimulation for all treatments, thus on 6 applications per year for below-cut stimulation on 2-inch-wide bands in half spiral tapping at 100% intensity. However, in commercial practice at Harbel Plantation, below-cut stimulation on bark of first or second renewal is usually on 3-inch bands and only twice a year, thus these trees are under stimulation for only 6 months of the year. For commercial and experimental methods in older rubber, which is stimulated more intensively, see ROSS and DINSMORE (1971).

The 2 stimulation techniques used in practice, viz. below-cut and above-cut stimulation, give a very different type of yield response (see e.g. ANLIKER and SCANLON, 1965). With below-cut stimulation, very high yields are obtained immediately after application, but these decline rapidly and yields fall to about untreated control level when the treated bark has been tapped off. With weekly above-cut stimulation, a more uniform response level is obtained. Compare in this respect results with these methods for different periods in exps 42–45. Yield curves for different stimulants (e.g. 2,4-D and ethephon) follow the same pattern. The type of yield response to stimulation of guide lines appeared to have much in common with that of below-cut stimulation; however, the peak in production was obtained a few days later. An impression of the yield curves with these 2 methods is obtained when yield responses in exps 44–47 are compared over different periods of yield recording. In Exp. 46, yields of each tapping were determined during the first month of stimulation. The largely schematic yield curves, given in Fig. 22, are based on these and other experimental data. The curves are merely given to show trends in yield responses; their actual level strongly depends on type of stimulant, concentration and planting material. In

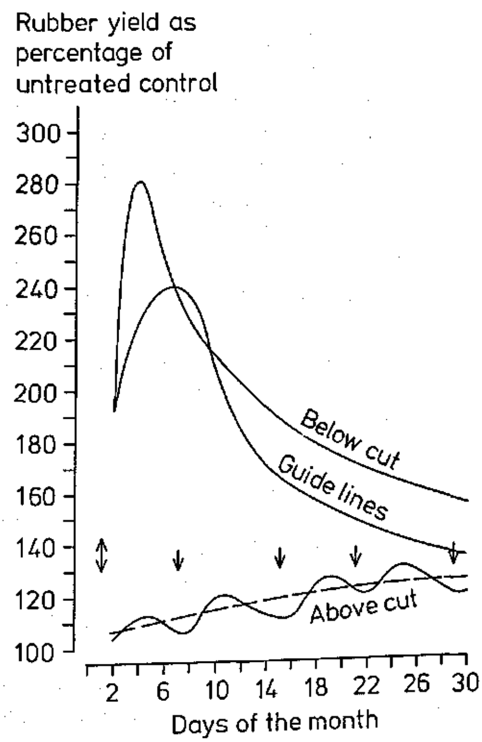


FIG. 22. Tentative yield curves for different stimulation methods over 15 tapping days since commencement of stimulation on the first day of the month. The arrows refer to stimulation dates. Tapping was on the even days of the month (S/2.d/2.100%). Below-cut and guide line stimulation was with ethephon and above-cut stimulation wilh 2,4-D in Treseal.

above-cut stimulation, it took several weekly applications before production reached a high and more or less constant level; generally, responses were highest on the second tapping day after an application.

Results obtained with above-cut application of 2,4-D in aqueous media (with and without captafol and other admixtures; see Section 6.3.1.) were discussed in a previous article (SCHREURS, 1971). It may be stressed that the thicker and rather uniform bark renewal, obtained with low concentrations of 2,4-D, might be an important and positive side-effect of this stimulation method on trees with thin bark renewal.

With ethephon in aqueous media, applied weekly above the cut, yield responses were very low in 0.25% concentration; much higher yields were obtained in 1% concentration (6.3.2.). It is possible that in low concentration ethephon is more readily disintegrated with subsequent loss of effectivity. It is stable in aqueous solutions below a pH of 3.5; above that level, the higher the pH the more rapid is the disintegration. Exceptional high yields were reported by ROSS and DINSMORE (1971) with ethephon, when applied weekly above the cut in 2.5% concentration in palm oil; in one experiment, tapped S/2.d/2.100%, yield increase amounted to 338% as percentage of the untreated control over a 4-month period.

Results of experiments with stimulation of guide lines are given in Section 6.3.3.; different aspects of this technique were already discussed in Section 6.2.1. It is of interest to note that yield increase with ethephon was also obtained when it was applied to unscraped portions of guide lines and to very lightly scraped (outer cork removed only) bands below the cut. Although yield increase was small, results do indicate that ethephon can penetrate through the entire hard bast. Results of Exp. 47 suggest that 2,4-D has little effect when applied to scraped portions of guide lines, in contrast to ethephon, which was a very effective stimulant. A possible important advantage of stimulation of guide lines is that the actual tapping panel is not treated, subsequently lowering the risk of adverse effects of the treatment on future production. It is – of course – of much importance that the renewing bark is of normal yield potential as the ultimate aim of stimulation is to obtain maximum yields over the entire life span of the tree. Another approach is to aim for a longer period of exploitation of trees, in which case somewhat lower yields must be accepted (tapping at reduced intensity, combined with stimulation). Other advantages of guide line stimulation are that scraping and application of stimulant is easy and light work and costs are relatively low. However, more experimentation is needed, e.g. with respect to yield responses over longer periods and with respect to performance of bark renewal on the scraped and treated portions.

The tentative profitability calculations showed that rather small yield increase was required to compensate for stimulation costs under the described conditions (6.4.3.).

In view of the above, it is probably more important to put the emphasis in stimulation trials on safe methods (to ensure also high yields in the future) rather than on cheaper methods.

8. SUMMARY

Described are investigations, carried out in 1963 to 1971 in *Hevea brasiliensis* at the Firestone Plantation at Harbel in Liberia. Studied was the tapping panel disease, black thread, caused by the fungus *Phytophthora palmivora.* The emphasis of the investigations was on control of the disease with the fungicide captafol (Difolatan). Another line of investigation was yield stimulation with 2,4-D (salts and esters of 2,4-dichlorophenoxyacetic acid) and ethephon (2-chloroethylphosphonic acid; commercial formulation named Ethrel), to combine application of yield-stimulants above the cut with application of captafol for black thread control. A new method of yield stimulation was tested: application of ethephon to scraped portions of the vertical guide lines.

General information on rubber in Liberia is given in sections 1, 2 and 3. Rubber is the most important cash crop grown in Liberia and accounted for 20% of total exports in 1969. Liberian rubber production amounted in 1970 to 2.2% of world production of natural rubber. Particulars on rubber cultivation at the Firestone Plantation at Harbel are given in Section 2. On this plantation about 25,000 ha of rubber are in production. There are 2 distinct seasons, a dry season from November to April and a rainy season from May to October. Production is lowest in the middle of the dry season when trees are wintering and refoliating.

The economic importance of diseases in *Hevea* is difficult to assess as the damage depends on local conditions, which also may change with time. Moreover, very different types of damage must be compared. Within these limits it was concluded that diseases are likely to be of less economic importance in Liberia than in many other rubber producing countries. The most important diseases probably are: black thread, root rot diseases (*Fomes* and *Armillaria*) and leaf diseases (*Helminthosporium* and *Gloeosporium*). Brown bast – the result of a physiological disorder – is another very damaging disease. Pests are generally of minor importance (1).

A review is given of all known diseases, pests and other causes of damage of *Hevea* in Liberia (3). It is remarkable that bird's eye leaf spot (caused by *Helminthosporium heveae*) was such an important leaf disease in young plantings of 4 to 8 years old; in the Far East, the damage is mainly confined to the nurseries. Wide-spread damage by patch canker (caused by *Pythium vexans*), done to the root collar, is also rather uncommon in most *Hevea* growing countries. Mouldy rot, a known tapping panel disease in the Far East and caused by the fungus *Ceratocystis fimbriata,* was never encountered in Liberia.

Black thread disease

Literature on different aspects of this disease is reviewed, viz. on symptoms and damage (4.1.1.) and on the causal agent, sources of infection, dissemination and predisposing factors (4.2.1.). In Liberia, black thread is often the most im-

portant disease in plantings of above average susceptibility. Highly susceptible *Hevea* clones, planted on a large scale, are BD 5 and Har 1. These clones are also highly susceptible to patch canker (4.2.3.).

Black thread causes rotting of the renewing bark. The recently tapped portion of the panel is subject to infection during the rainy season. The diseased bark deteriorates, the cambium is killed and, eventually the wood is exposed. In severe cases, large parts of the tapping panel are affected, rendering subsequent tapping impossible. Secondary infections may increase damage (pinhole borers; the fungi *Ustulina zonata* and *Pythium vexans*). Older trees with a severe black thread history are probably also more liable to wind damage (trunk snap); sections through stems of such trees showed irregular wood formation with necrotic parts (4.1.3.). Generally, the wounds start healing with the onset of the dry season. However, healed wounds have irregular bark, which is difficult to tap and possibly of lower yield potential. Progress of healing tissue was generally between 0.75 and 1.5 mm per month (4.1.2. and 6.3.5.2.). Healing was slowest during the driest months. Application of 2,4-D to artificially made wounds promoted healing (6.3.5.2.). Black thread is most predominant in August and September at Harbel, the months with little sunshine, relatively low temperature and highest rainfall (2 and 4.2.2.).

It is known that infection takes place by means of sporangia or their zoospores. Severe infections built up on panels protected against rain with polyethylene sheets, thus visibly dry panels can also be infected; a higher than normal relative humidity is maintained under such aprons (4.2.2.).

There is a distinct positive correlation between the incidence of new and old black thread damage on the same tree (4.2.4.). It is not clear whether the old wounds are a source of infection to the underlying portion of the panel, tapped during the next rainy season; disinfection of the old wounds had no effect on later disease incidence (4.2.8.). At any rate, as the disease in general builds up each year on the same trees — also in clonal plantings – it might be advisable to take trees with a severe black thread history out of tapping for the entire rainy season; such a measure will also prevent spread of the disease to neighbouring trees (4.2.7.). The disease is generally more predominant in low-lying areas close to swamps, probably because of the more humid microclimate (4.2.5.). The tapper is probably an important factor in the spread of the disease. He spreads the disease presumably with his hands; the tapping knife is probably of lesser importance (4.2.6.).

A rather unusual case of black thread damage on panel marks is also reported. It was concluded that when new panels are laid during the rainy season, the drawn channels should be protected with a fungicide (4.1.5.).

Control of black thread

Various fungicides were tested because the product used in practice (Treseal, a petroleum jelly) gave unsatisfactory disease control in *Hevea* clones of above average susceptibility. In bio-assays (5.3.), captafol proved to be a stronger fungicide against *P. palmivora* than the related compound captan, which latter chemical was of promise in CARPENTER's experiments (1954). Next, these and other fungicides were tested in field trials.

Most field experiments had a randomized block or a replicated tree plot design. The trials were laid out in such a way that the damage done in the previous rainy season was of the same level in all treatments, in order to level the chances of infection. The damage was evaluated according to a scale: '0' (no damage) to '6' (maximum damage possible). The panels were exposed to natural infections; no use was made of artificial inoculation (5.2.2.2. and 5.2.2.3.).

Very satisfactory disease control was obtained with 1% captafol suspension in water, applied weekly with a brush on a 2–2.5 cm wide strip immediately above the cut (5.4 and 5.5.). Antimucin, an organic mercury compound – much used in the Far East – gave very little protection when applied weekly in 0.8–1.0% concentration (5.5.1.). Under the described conditions the optimum concentration for captafol was probably about 1% (5.5.2.). In Malaya, Difolatan is recommended in 2% concentration, to be applied after every tapping. In most experiments, 0.1% Ortho spray sticker was added to the suspension, although it has not yet been proved that this gives better disease control. Results indicate that products with very effective sticking properties (such as high concentrations of wax emulsions) might even lower the effectiveness of captafol (5.5.3.). A suitable colouring agent for captafol suspensions in water is yellow iron oxide, added to make captafol application to the panel visible (supervision). However, some Sterox NJ (a synthetic detergent) should be added to keep the powders better in suspension. Very satisfactory results were obtained with the following mixture in experiments and commercial practice: 1.25% Difolatan 80 WP (containing 1% captafol) + 1% yellow iron oxide (grade YO-2087) + 0.1% Ortho sticker + 0.01% Sterox NJ in water (5.5.4.).

It should be emphasized that a homogeneous suspension must be prepared or otherwise disease control is less effective. Therefore, a slurry of the Difolatan powder should first be prepared. If too much water is added, the aggregated Difolatan particles do not separate and an unstable suspension is immediately obtained. After this stage, more water should be added whilst stirring, and then the other ingredients added. The whole procedure can be simplified and speeded up with the aid of strong electric agitators. The quantity of water added at one time to the Difolatan powder is then less critical. It is practical, however, to prepare first a concentrate of 20 times the strength applied to the trees and to dilute with water on the day the applications have to be made. The concentrate should be made up no earlier than 1 month in advance because of decomposition of captafol during prolonged storage (5.7.).

The residue of captafol on treated panels is rather persistent; however, most of it had disappeared 5–6 months after application (disintegration, dissolution, particles dropped off, particles washed off by rain). This fungicide does not penetrate into the living tissues of the bark (5.6.). It is likely that the protective action of captafol is based on the traces of it which dissolve in the water film on wet panels (7).

Side effects of captafol applications were also studied (5.5.8.). Chances are extremely remote that normal captafol applications have adverse effects on the physical properties of the rubber (5.5.8.1.). Latex yield and yield potential of treated renewing bark were also normal (5.5.8.2. and 5.5.8.3.). However, captafol treatments have a temporarily retarding effect on the activity of the cork cambium, initially reducing hard bast and cork formation; soft bast renewal is about normal from the beginning. It is to be expected that the initial differences in bark thickness between treated and untreated panels will have disappeared when the bark has fully matured and is to be tapped again at the age of 8 to 10 years (6.3.5.1.). Bark renewal can be improved when low concentrations of 2,4-D are added to the captafol mixture.

Yield stimulation

This subject is introduced with a brief review of literature. Illustrations are given of 4 stimulation techniques (Fig. 15), which are:

a. weekly above-cut stimulation.
b. stimulation of a scraped band of bark parallel to and below the tapping cut.
c. stimulation of lightly scraped portions of the vertical guide lines.
d. stimulation of lightly scraped, vertical narrow strips of bark below the cut.

The experiments had a replicated tree plot design and layout was based on pretreatment yield data. So, trees were allocated to treatments in such a way that the mean production level of each treament was about the same. Layout can also be based on pretreatment girth measurements as yield and girth of the stem are positively correlated in clonal plantings. However, the correlation between later yield and pretreatment yield appeared to be significantly higher than between later yield and girth (6.2.2. and 6.2.3.). For experiments of relatively short duration, taken in older plantings, pretreatment yield data are definitely to be preferred.

Important yield increase was obtained with weekly above-cut application of 2,4-D in aqueous media (with and without captafol and other admixtures), although lower than with 2,4-D in the petrolatum Treseal. However, 2,4-D in Treseal is only applied during the last tapping cycle in commercial practice, because the treated bark becomes greatly proliferated. There is much less bark proliferation with 2,4-D in aqueous media. This method is fairly promising for younger plantings and for older rubber with thin bark renewal; in concentrations up to 0.25% the thickness of the renewing bark can be increased without much bark proliferation (6.3.1. and 6.3.5.1.).

With Ethrel in aqueous media (with and without captafol and other admixtures), also applied weekly above the cut, still higher yield increase was obtained, viz. in a concentration of 1% ethephon. Yield increase was very low in 0.25% concentration, probably because ethephon was disintegrated (the higher the pH the faster is disintegration). Yield increase was very high in 2.5% concentration (6.3.2.).

The novel stimulation technique, i.e. application of Ethrel in palm oil on scraped portions of the vertical guide lines, showed much promise. In a concentration of 5% ethephon, applied to 4 inches (10 cm) of each of the 2 guide lines, yield increase was about of the same level as with 1% ethephon in water, applied to a 2-inch-wide scraped band below the cut (6.3.3.). A detailed description of this technique was given in Section 6.2.1. The preliminary results indicated the following:

1. A portion of each of the 2 guide lines should be treated.
2. It is of little importance which portion of each guide line is treated (above or below the cut). However, it is impractical to treat the front channel below the cut because the spout is positioned there.
3. An effective length is 10 cm per guide line. Treatment of longer portions gave relatively low extra yield increase. It is worth trying to treat shorter portions, e.g. 5 cm per guide line.
4. The same portion can be scored and treated for a second time within a few months. When a portion of 10 cm per guide line is treated then the trees can be stimulated every 2 months, provided bark consumption is at least 2.5 cm per month, the condition or the bark allows for a second treatment and continuous stimulation is wanted.
5. Scraping of the guide lines is essential to obtain effective penetration of ethephon. Only the dead bark layers are removed.
6. Ethrel should be applied in palm oil rather than in aqueous media (higher yield response and easier to apply).
7. The optimum concentration is presumably 5% ethephon or higher.

The conclusion was drawn that this method merits further testing since high yield response was obtained at low Ethrel consumption. Moreover, the tapping panel itself is not treated, so that the risk of undesirable side-effects on bark renewal should be lower.

Results of measurements of bark thickness suggest that ethephon applications (above-cut, below-cut or on guide lines) have no or little effect on bark renewal (6.3.5.1.). However, it is still unknown whether bark renewal will continue to be normal when trees are stimulated intensively with high concentrations of ethephon for many years, as ultimate exhaustion of the tree – because of excessively high withdrawal of latex – may have adverse effects on growth. In younger plantings, girthing of the trees should be closely watched.

This chapter on yield stimulation is concluded with some considerations on effectiveness and profitability of different stimulation methods with Ethrel (6.4.). The calculations showed that relatively small increases in yield already compensate for the costs of rather expensive stimulation methods under the described conditions when the normal yield level is at least 900 kg dry rubber per ha and per year. Therefore, it is probably more important to put the emphasis in stimulation trials on safe methods, which are likely to have little effect on future yields, rather than on cheaper methods (7).

9. SAMENVATTING

Streepjeskanker-ziekte, bestrijdingsmethoden en stimulatie van de produktie in Hevea brasiliensis in Liberia.

Gedurende de jaren 1963 tot 1971 was ik als fytopatholoog verbonden aan het Botanical Research Department van Firestone Plantations Company te Harbel in Liberia. De tapvlakziekte streepjeskanker, veroorzaakt door *Phytophthora palmivora*, werd het meest diepgaand bestudeerd. Het accent van het onderzoek lag op de bestrijding van deze ziekte met het fungicide captafol (Difolatan). Voorts werd onderzoek verricht op het gebied van stimulatie van de rubberproduktie met 2,4-D (zouten en esters van 2,4-dichloorfenoxyazijnzuur) en ethephon (2-chloorethylfosfonzuur; handelsmerk: Ethrel) met het doel om de toediening van deze middelen te combineren met die van captafol voor de bestrijding van genoemde tapvlakziekte. Tevens werd een nieuwe stimulatiemethode beproefd door toediening van ethephon aan gedeelten van de verticale 'guide lines' (linker en rechter begrenzing van het tapvlak).

Algemene informatie over de rubbercultuur in Liberia wordt verstrekt in de eerste drie hoofdstukken. Rubber is het belangrijkste industriële gewas in Liberia; de produktie bedroeg 20% van de totale uitvoer in 1969 en 2,2% van de wereldproduktie aan natuurrubber in 1970. Op de Firestone plantage te Harbel is ongeveer 25.000 ha rubber in produktie. Twee seizoenen zijn te onderscheiden, t.w. een droge tijd van november tot april en een natte tijd van mei tot oktober. De produktie is het laagst in het midden van de droge tijd als de bomen ruien en nieuw blad vormen.

Verhoudingsgewijs wordt aan de rubbercultuur in Liberia waarschijnlijk minder schade toegebracht door ziekten en plagen dan in de meeste andere rubber producerende landen. Tot de belangrijkste ziekten behoren in Liberia: streepjeskanker, wortelziekten (*Fomes* en *Armillaria*) en bladziekten (*Helminthosporium* en *Gloeosporium*). Bruine binnenbast – een fysiologische ziekte – behoort ook tot deze zeer schadelijke groep. Plagen zijn in het algemeen van minder belang. 'Mouldy rot', een bekende tapvlakziekte in Z.O. Azië en veroorzaakt door de schimmel *Ceratocystis fimbriata*, werd in Liberia niet gesignaleerd.

Een volledig overzicht van alle bekende ziekten, plagen en andere soorten van schade in Liberia wordt gegeven in Hoofdstuk 3. Hieruit blijkt dat de bladziekte, veroorzaakt door *Helminthosporium heveae*, in het verleden zeer veel schade heeft gedaan in jonge aanplantingen van 4 tot 8 jaar oud, terwijl in het Verre Oosten deze schade doorgaans beperkt blijft tot de kweekbedden. Aantasting van de wortelkraag door 'patch canker', veroorzaakt door de schimmel *Pythium vexans*, komt veelvuldig voor in Liberia, terwijl dit ziektebeeld weinig bekend is in de meeste andere landen.

Streepjeskanker

Dit onderwerp wordt uitvoerig behandeld in Hoofdstuk 4. Streepjeskanker is in Liberia vaak de belangrijkste ziekte. De op grote schaal aangeplante klonen BD 5 en Har 1 zijn zeer vatbaar en bovendien zeer gevoelig voor 'patch canker' (4.2.3.).

Streepjeskanker veroorzaakt rotting van de herstellende bast. De recentelijk getapte bast wordt geïnfecteerd in de natte tijd. Te Harbel treedt de meeste schade op in augustus en september, maanden met weinig zonneschijn, betrekkelijk lage temperaturen en hoge regenval (2 en 4.2.2.). In ernstige gevallen worden grote delen van het tapvlak aangetast, waardoor zulke bomen uiteindelijk ontapbaar worden. Secundaire aantastingen kunnen de schade nog vergroten (boorders en de schimmels *Ustulina zonata* en *Pythium vexans*). Oudere bomen, welke jaren achtereen op ernstige wijze werden aangetast, zijn waarschijnlijk ook zeer wind-gevoelig (stam knapt af op het tapvlak). Doorsneden van de stam van zulke bomen laten onregelmatig houtweefsel zien met necrotische plekken (4.1.3.). Bij het begin van de droge tijd komt de rotting doorgaans tot stilstand en vormt zich een helend weefsel langs de rand van de wond. Dit weefsel, dat de wond doet sluiten, groeide onder gunstige omstandigheden met ca 0,75 tot 1,5 mm per maand; in de droge tijd is de groei doorgaans zeer gering (4.1.2. en 6.3.5.2.). Heling van kunstmatig gemaakte wonden werd bevorderd door behandeling met 2,4-D.

Het is bekend dat infectie plaats vindt door sporangia en hun zoösporen. Klaarblijkelijk kan op het oog droog lijkende bast ook geïnfecteerd worden daar tapvlakken, welke tegen regen beschermd werden met plastic schorten, op ernstige wijze werden aangetast; de relatieve vochtigheid onder zulke schorten is echter hoger dan normaal (4.2.2.).

Er is een duidelijk positief verband tussen het voorkomen van nieuwe en oude schade op eenzelfde boom (4.2.4.). Het is niet bekend of de oude wonden een infectiebron zijn voor lager gelegen delen van het tapvlak. Uitwendige ontsmetting van zulke wonden had geen invloed op de mate van aantasting in het volgende regenseizoen (4.2.8.). Aangezien de ziekte elk jaar meestal op dezelfde bomen uitbreekt – ook in klonale aanplantingen – kan het aanbeveling verdienen om bomen met een ernstige streepjeskanker-historie voor de duur van de natte tijd uit de tap te nemen. Op deze wijze voorkomt men tevens de verspreiding naar naburige bomen (4.2.7.). Op lage gronden (dicht bij moerassen) doet de ziekte doorgaans meer schade, waarschijnlijk vanwege het vochtiger microklimaat (4.2.5.).

De tapper speelt zeer waarschijnlijk een belangrijke rol bij de verspreiding van de ziekte. Vermoedelijk brengt hij de ziekte met zijn handen over; het tapmes is in dit verband waarschijnlijk van minder belang (4.2.6.).

Een bizondere vorm van streepjeskanker-schade wordt nog genoemd, toegebracht aan de ondiepe tapsnede, welke bij verwisseling van het tapvlak wordt gemaakt om aan te geven op welke hoogte de tap op deze zijde van de stam dient aan te vangen. Wanneer dergelijke merken in de natte tijd worden aangebracht dienen deze derhalve preventief met een fungicide te worden behandeld (4.1.5.).

Bestrijding van streepjeskanker

Vele fungiciden werden beproefd omdat het middel dat in de praktijk werd gebruikt (Treseal, een vetachtige substantie), onvoldoende bescherming gaf in de meer gevoelige *Hevea* klonen. In 'bio-assays' bleek het fungicide captafol de groei van *P. palmivora* sterker te remmen dan de verwante verbinding captan, welk middel veelbelovende resultaten had gegeven in proeven van CARPENTER (1954).

De meeste veldproeven hadden een 'randomized block design' of een 'replicated tree plot design'. De proeven werden op zodanige wijze uitgevoerd dat de oude schade van hetzelfde niveau was in alle behandelingen, teneinde de infectiekansen gelijkelijk te verdelen. De schade werd beoordeeld met behulp van een waarderingsschaal van '0' (geen aantasting) tot '6' (maximale schade). De tapvlakken waren aan natuurlijke infecties blootgesteld en werden niet kunstmatig geïnoculeerd (5.2.2.2. en 5.2.2.3.).

Zeer bevredigende resultaten werden verkregen met 1 % captafol suspensie in water, wekelijks met een kwast aangebracht op een strook bast van 2–2,5 cm breed direct boven de tapsnede (5.4. en 5.5.). De organische kwikverbinding Antimucin – veel gebruikt in het Verre Oosten – gaf zeer onvoldoende bescherming in een concentratie van 0,8–1,0 % (5.5.1.). De optimale concentratie voor captafol was waarschijnlijk ca 1 % (1,25 % van Difolatan 80 WP) onder de beschreven omstandigheden (5.5.2.). In Malakka wordt Difolatan 80 WP echter aanbevolen in een concentratie van 2 %, toe te passen na iedere tapping. In de meeste veldproeven werd 0,1 % Ortho spray sticker aan de suspensie toegevoegd, ofschoon uit proeven niet duidelijk is gebleken dat hiermede een betere ziektebestrijding werd verkregen. Zeer effectieve hechtmiddelen (zoals hoge concentraties van was emulsies) leken de werkzaamheid van captafol zelfs nadelig te kunnen beïnvloeden (5.5.3.). Een geschikt kleurmiddel voor captafol suspensies is geel ijzeroxide om de toepassing beter zichtbaar te maken (supervisie). In dit geval dient echter een weinig van een synthetische 'detergent' te worden toegevoegd (Sterox NJ) om de poeders beter in suspensie te houden. In proeven en in de praktijk werden met het volgende mengsel zeer bevredigende resultaten verkregen: 1,25 % Difolatan 80 WP (equivalent aan 1 % captafol) + 1 % geel ijzeroxide (type YO-2087) + 0,1 % Ortho spray sticker + 0,01 % Sterox NJ in water (5.5.4.).

Het resultaat van captafol behandelingen hangt sterk af van de homogeniteit van de suspensie. Het verdient aanbeveling eerst een slurry van het Difolatan poeder te bereiden. Als te veel water wordt toegevoegd wordt direct een instabiele suspensie verkregen, daar samengeklonterde deeltjes dan niet uiteen vallen. Vervolgens wordt aan de slurry meer water toegevoegd, alsmede de andere bestanddelen. Bereiding van de suspensie kan worden vereenvoudigd met behulp van sterke electrische mixers, in welk geval direct meer water aan het poeder kan worden toegediend. De ervaring heeft geleerd dat in de praktijk beter eerst een concentraat van 20 maal de normale sterkte kan worden aangemaakt, te verdunnen op de dag van toepassing. Het concentraat is minstens een maand houdbaar (5.7.).

Het residue van captafol op het tapvlak is tamelijk persistent maar was na 5 á 6 maanden grotendeels verdwenen (ontleding, oplossing, afvallen van deeltjes, afvoer van deeltjes door regen). Dit fungicide dringt de levende bast niet binnen (5.6.). De beschermende werking van captafol berust waarschijnlijk op de oplossing van minimale hoeveelheden van het middel in de waterfilm op natte tapvlakken (7).

Neveneffecten van de behandeling werden tevens bestudeerd (5.5.8.). De kans is bizonder klein dat normale toepassing van captafol een nadelige invloed heeft of de fysische eigenschappen van het rubberprodukt (5.5.8.1.). Latexproduktie en produktiecapaciteit van de herstellende bast waren ook normaal (5.5.8.2. en 5.5.8.3.). Wel doen behandelingen met captafol de activiteit van het kurkcambium afnemen, waardoor aanvankelijk minder harde bast en kurk worden gevormd. Op het herstel van de zachte bast heeft het middel geen invloed. Het is te verwachten dat de aanvankelijke verschillen in bastdikte tussen behandelde en onbehandelde tapvlakken verdwenen zullen zijn als de bast volgroeid is en wederom getapt wordt (6.3.5.1.). Het bastherstel kan worden bevorderd door lage concentraties 2,4-D aan het captafol-mengsel toe te voegen.

Stimulering van de rubberproduktie

Dit onderwerp wordt ingeleid door een kort overzicht van de literatuur. Illustraties worden gegeven van vier stimulatiemethoden (Fig. 15), t.w.:

a. wekelijkse behandeling boven de tapsnede ('above-cut'),
b. behandeling van een geschraapte strook bast evenwijdig aan en direct onder de tapsnede ('below-cut'),
c. behandeling van licht geschraapte, verticale smalle stroken aan weerszijden van het tapvlak ('guide lines'),
d. behandeling van licht geschraapte, verticale smalle stroken onder de tapsnede.

Proefnemingen werden gedaan met de eerste drie methoden. Deze veldproeven hadden een 'replicated tree plot design', waarbij de uitvoering gebaseerd was op opbrengstcijfers, verzameld over een periode voorafgaande aan de behandeling. De bomen werden op zodanige wijze over de behandelingen verdeeld dat het gemiddelde produktieniveau van iedere behandeling ongeveer gelijk was. Het is ook mogelijk om van omtrekcijfers uit te gaan daar stamdikte en rubberproduktie positief gecorreleerd zijn in klonale aanplantingen. Er bleek echter een betere correlatie te bestaan tussen toekomstige produktie en voorafgaande produktie dan tussen toekomstige produktie en stamdikte (6.2.2. en 6.2.3.). In verband hiermede moet – zeker voor kortlopende proeven in oudere aanplantingen – de voorkeur worden gegeven aan vóór-produktiecijfers.

Een belangrijk hogere produktie werd verkregen met 2,4-D in water (met en zonder captafol en andere bijmengsels), wekelijks toegediend boven de tapsnede. De standaard-behandeling, 2,4-D in Treseal (een vetachtige substantie), was echter nog effectiever. In de praktijk wordt 2,4-D in Treseal uitsluitend gedurende de laatste tapcyclus gebruikt, dus op bast die niet meer getapt zal worden, daar het bastherstel onregelmatig is. Met 2,4-D in water is het bastherstel veel regelmatiger en daarom is deze methode bepaald interessant voor stimulering van jongere bomen. Voor oudere bomen met een dun bastherstel biedt deze behandeling ook goede perspectieven omdat in een concentratie tot 0,25% een dikker bastherstel wordt verkregen zonder noemenswaarde woekeringen (6.3.1. en 6.3.5.1.).

Met Ethrel in water (met en zonder captafol en andere bijmengsels), en eveneens toegepast boven de tapsnede, werden nog hogere produkties verkregen (1% ethephon). In een concentratie van 0,25% werd de produktie zeer weinig gestimuleerd, waarschijnlijk vanwege ontleding van de actieve stof (bij hogere pH snellere ontleding). Zeer hoge opbrengsten werden verkregen in een concentratie van 2,5% (6.3.2.).

Veelbelovend is een nieuwe stimulatiemethode, waarbij Ethrel in palmolie wordt aangebracht op licht geschraapte delen van de linker en rechtei begrenzing van het tapvlak ('guide lines'). In een concentratie van 5% ethephon, toegediend over een lengte van 10 cm van elke 'guide line', werden even grote produkties verkregen als met 1% ethephon in water, toegediend aan een 5 cm brede strook geschraapte bast onder de tapsnede ('below cut': 6.3.3.). Een gedetailleerde beschrijving van deze nieuwe methode is gegeven in 6.2.1. De proeven hebben het volgende aangetoond:

1. Een deel van beide 'guide lines' dient te worden behandeld.
2. Het is van minder belang welk deel wordt behandeld (boven of onder de tapsnede). Behandeling van de rechter 'guide line' onder de tapsnede stuit op praktische bezwaren omdat de 'spout' zich in dit gootje bevindt.
3. Een effectieve lengte is 10 cm per 'guide line'. Behandeling van langere delen gaf een betrekkelijk geringe extra meeropbrengst. Stimulatie van kortere stukken, b.v. van 5 cm, verdient nader onderzoek.
4. Eenzelfde gedeelte kan binnen een tijdsbestek van enkele maanden voor een tweede maal geschraapt en gestimuleerd worden. Wanneer 10 cm per 'guide line' behandeld wordt kunnen de bomen iedere 2 maanden gestimuleerd worden, vooropgesteld dat het bastverbruik minstens 2,5 cm per maand is, de bast een tweede behandeling verdraagt en continue stimulatie gewenst is.
5. Het schrapen van de bast is noodzakelijk om een goede penetratie van ethephon te bewerkstelligen. Slechts de dode bastlagen behoeven te worden verwijderd.
6. Palmolie is een betere 'carrier' dan water voor deze toepassing van Ethrel (gemakkelijker op te brengen en hogere opbrengsten).
7. De optimale ethephon concentratie is vermoedelijk 5% of hoger.

Geconcludeerd werd dat beproeving van deze methode op grotere schaal stellig gewettigd is daar hoge produkties werden verkregen bij een laag Ethrel verbruik. Voorts is er weinig kans op abnormaal bastherstel omdat het tapvlak zelf niet wordt behandeld.

De diverse toepassingen van ethephon (boven en onder de tapsnede, alsmede op 'guide lines') hebben waarschijnlijk weinig of geen invloed op de diktegroei van de herstellende bast (6.3.5.1.). Het is echter niet bekend of het bastherstel zich normaal blijft ontwikkelen bij intensieve stimulatie gedurende een lange periode, daar uitputting van de boom zijn weerslag zou kunnen hebben op de groei. In jongere aanplantingen dient de diktegroei van de stam in dit soort proeven nauwlettend gevolgd te worden.

Dit hoofdstuk over stimulatie werd besloten met enkele beschouwingen over effectiviteit en rentabiliteit van de diverse stimulatiemethoden met Ethrel (6.4.). De cijfers tonen aan dat tamelijk geringe meeropbrengsten reeds de kosten dekken van betrekkelijk dure methoden onder de beschreven omstandigheden en bij een normale produktie van tenminste 900 kg droge rubber per ha en per jaar. Daarom is het waarschijnlijk van meer belang om in stimulatieproeven de nadruk te leggen op veilige methoden, welke ook goede toekomstige produkties garanderen, dan op goedkopere methoden (7).

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11. APPENDIX

Exp. 1 (1964): *black thread incidence under rain guards on trees, tapped at a high and a low level*

Clone BD 5, planted in 1945, tapped alternate daily. Half of the number of trees tapped high (about 170 cm above union) on virgin bark and the other trees low (about 40 cm above union) on first bark renewal. Randomized block trial with 10 blocks, 6 plots per block and 5 trees per plot. Clear and black polyethylene rain guards were tested. The sheets measured 71 × 91 cm and were 0.05 mm thick. The sheets were attached with grease above the tapping cut on lightly scraped bark and fastened with a thin wire. The rain guards were hung up mid June and removed mid November 1964. To ensure that the disease could build up, no fungicides were applied. The disease incidence was evaluated at the end of November. The total length of the diseased and dead parts of the panel was measured parallel to the tapping cut. The total length was then expressed as a percentage of the length of the tapping cut.

Treatments	Percentage of panel damaged by black thread in 1964	Duncan test at 5% level
1. high panel – clear rain guard	15.3	a
2. high panel – black rain guard	17.9	a
3. high panel – unprotected panel	21.8	a
4. low panel – clear rain guard	30.1	b
5. low panel – black rain guard	36.6	b c
6. low panel – unprotected panel	43.3	c

$S_m = 2.582$ ($n_2 = 45$)

Exp. 6 (1965): *black thread control*

Clone BD 5, planted in 1945, tapped alternate daily on first bark renewal at about 125 cm above union. Randomized block trial with 4 blocks, 13 plots per block and 15 trees per plot. Average pretreatment damage (1964) amounted to 3.16 (range between treatment means: 0.58). Application of fungicides was every fourth day (after 2 tappings) for Treseal and Treseal-mixtures and after each tapping for all other treatments. The panels were protected against rain with polyethylene sheets, except for one Treseal treatment. Plyac spreader(sticker (0.035%) and Agral wetting agent (0.02%) were added to the fungicides applied in water. The emulsions were made with technical captan and captafol, using dimethyl sulphoxide (DMSO) as solvent, xylol and emulsifier. Results were evaluated December 13–17, 1965.

Treatments	Mean 1965 damage	Duncan test at 5% level
With rain guards:		
1% captafol suspension in water	0.15	
0.2% captafol suspension in water	0.80	
Treseal + 1% captafol + 7% DMSO	0.83	
0.2% captafol emulsion in water	0.90	
Treseal + 1% captan	1.12	
Treseal	1.21	
Treseal + 1% laptan + 20% DMSO	1.25	
1% captan suspension in water	1.29	
Treseal + 1% captafol	1.31	
0.3% Mycocide Latex in water	1.60	
0.2% captan emulsion in water	1.78	
0.2% captan suspension in water	1.86	
Without rain guards:		
Treseal	2.32	

$S_m = 0.3248$ ($n_2 = 36$)

Exp. 8 (1966): *black thread control and effect of treatments on rubber yield*

Clone BD 5, planted in 1945, tapped alternate daily on first bark renewal at about 100 cm above union. Replicated tree plot design with 86 trees per treatment. Average pretreatment damage amounted to 3.07 in 1964 (range between treatment means: 0.31) and to 0.82 in 1965 (range between treatment means: 0.06). Average pretreatment yield was for 21 tappings during April/May 1966: 37.3 g dry rubber per tree and per tapping (range between treatment means; 0.7). The treatments were applied once a week from mid May till the beginning of November. Black thread control results were evaluated mid November 1966. The rubber yields were determined monthly from mid May through September (56–59 tappings).

Treatments

1. 1% captafol + 0.1% Ortho sticker in water
2. 50% Santar A in water (10% after July 6)
3. 50% Mobilcer 67 in water (25% after July 6)
4. 1% captafol + 10% Santar A in water
5. 1% captafol + 25% Mobilcer 67 in water
6. Treseal
7. Untreated control

Results

Mean 1966 black thread damage

Treatment No.	Damage	Duncan test at 5% level
4	0.85	
1	1.05	
5	1.27	
6	1.95	
7	2.98	
3	2.99	
2	3.07	
$S_m =$ (for $n_2 = 510$)	0.1462	

Mean rubber yields over about 5 months as percentage of untreated control

Treatment No.	Yield	Duncan test at 5% level
1	107.0	
5	103.8	
4	102.8	
2	101.8	
3	100.8	
7	100.0	
6	96.3	
	2.1570	

Yield of untreated control as g dry rubber per tree and per tapping: 58.4

Exp. 11 (1966): *black thread control and yield stimulation*

Clone BD 5, planted in 1945, tapped alternate daily on first bark renewal at approximately 100 cm above union. Replicated tree plot design with 10 trees per treatment. Average 1964/1965 black thread damage amounted to 1.94 (range between treatment means: 0.51). Average pretreatment yield of cup coagulum was for 39–42 tappings during April/July 1966: 54.5 g per tree and per tapping (range between treatment means: 0.6). The treatments were applied once a week from July through October 1966. The black thread control results were evaluated mid November 1966. The rubber yields were determined monthly from mid July through October (44–45 tappings).

Treatments

1. 0.25% 2,4-D (butyl ester) in Treseal
2. 0.25% 2,4-D (sodium salt) + 10% Santar A + 1% captafol in water
3. 0.25% 2,4-D (sodium salt) + 25% Mobilcer 67 + 1% captafol in water
4. Treseal
5. 10% Santar A + 1% captafol in water
6. 25% Mobilcer 67 + 1% captafol in water

Results

Mean 1966 black thread damage			Mean rubber yields over 4½ months as percentage of Treseal treatment		
Treatment No.	Damage	Duncan test at 5% level	Treatment No.	Yield	Duncan test at 5% level
5	0.30	a	1	131.7	a
2	0.90	ab	2	126.3	a
6	1.50	b	3	123.4	a
3	1.50	b	5	102.3	b
4	1.80	b	4	100.0	b
1	3.85		6	93.0	b
S_m =	0.3463			3.803	
(for n_2 = 45)					

Yield of Treseal treatment as g dry rubber per tree and per tapping: 59.3

Exp. 16 (1967/'68): *black thread control, yield stimulation and bark renewal*

Clone BD 5, planted in 1943, tapped monthly periodic on first bark renewal at about 110 cm above union. Replicated tree plot design with 26 trees per treatment. Average pretreatment damage amounted to 0.81 for 1965/'66 (range between treatment means: 0.06). Average pre-treatment yield was for 62 tappings during March and May 1967: 27.5 g cup coagulum per tree and per tapping (range between treatment means: 1.4). All treatments were applied once a week during the tapping months of July, September and November 1967. During the months of January, March and May 1968 the applications were normally continued for treatments 2 and 5; captafol was omitted during these months in treatments 1, 3, 4 and 6. No further applications were made in treatments 7 to 10. These changes were made as the disease needs no treatment during the dry season. Black thread control results were evaluated at the end of December 1967 and separate evaluations were made on the portions of the panel tapped in July, September and November; the figures in the table are the means of these 3 evaluations per tree. Yields were determined monthly and refer to the production of cup coagulum (July 1967 through May 1968). The mean yields of the different tapping months are also given for stimulated against unstimulated treatments. The thickness of the renewing bark, tapped in July 1967, was measured 6 months later.

Treatments

1. 0.25% 2,4-D (Weedone) + 1% captafol (Difolatan-4-flowable) in palm oil
2. 0.25% 2,4-D (butyl ester) in Treseal
3. 0.25% 2,4-D (Weedone) + 1% captafol + 10% Santar A in water
4. 0.25% 2,4-D (Weedone) + 1% captafol + 0.5% Ortho sticker in water
5. 0.25% 2,4-D (Weedone) + 0.1% Ortho sticker in water
6. 0.25% 2,4-D (Weedone) + 1% captafol + 0.1% Ortho sticker in water
7. Treseal
8. 0.8% Antimucin WBR in water
9. 0.25% 2,4-D (Sesone) + 0.8% Antimucin WBR + 0.1% Ortho sticker in water
10. 1% captafol + 0.1% Ortho sticker in water
11. Untreated control

Results

Mean 1967 black thread damage			Mean rubber yield for one year tapping as percentage of untreated control		
Treatm. No.	Damage	Duncan test at 5% level	Treatm. No.	Yield	Duncan test at 5% level
1	0.71		1	147	
3	0.76		2	144	
7	0.94		3	136	
10	1.15		4	134	
4	1.27		5	131	
2	1.33		6	124	
6	1.37		7	115	
8	1.75		8	105	
11	1.90		9	102	
9	2.08		10	102	
5	2.26		11	100	
S_m = (for n_2 = 250)	0.170			4.799	

Yield of untreated control as g cup coagulum per tree and per tapping: 44.1

The mean damage was for all experimental trees (286 trees) on the portion of the panel tapped in different months:

July: 0.25
Sep.: 3.40
Nov.: 0.58

The mean yield was during the different tapping months for the stimulated treatments (1–6) and for the unstimulated treatments (7–11):

	Yield as g cup coagulum per tree and per tapping							
	Pretreatment		Experimental yields					
	Mar 67	May 67	Jul 67	Sep 67	Nov 67	Jan 68	Mar 68	May 68
unstimulated treatments	26.5	28.9	47.2	59.9	49.8	52.7	30.3	39.4
stimulated treatments	26.4	28.4	53.3	78.4	67.9	68.8	39.0	54.6
% yield increase for stimulated treatments			13	31	36	31	29	39

Mean thickness of renewing bark, tapped in July 1967 and measured 6 months later in mm for eight of the treatments

Treatm. No.	Living bark	Cork	Total bark
5	4.70	1.30	6.00
7	4.10	1.25	5.36
4	4.29	1.01	5.30
6	4.20	1.02	5.23
11	3.79	1.35	5.15
3	4.22	0.82	5.04
8	3.74	1.18	4.92
10	3.49	1.01	4.50

Exp. 18 (1967): *black thread control*

Clone BD 5, planted in 1948, tapped monthly periodic on first renewal (some trees on virgin bark) at approximately 125 cm above union. Randomized block trial with 3 blocks, 7 plots per block and ± 15 trees per plot. The average 1965/'66 black thread damage amounted to 0.67 (range between treatment means: 0.09). The fungicides were applied twice a week during the tapping months of July, September and November. The results were evaluated on December 29–30, 1967 and this was done separately on the portions of the panels tapped in July, September and November; the figures in the table are the means of these three evaluations per tree.

Treatments	Mean 1967 damage	Duncan test at 5% level
1% captafol + 0.1% Ortho sticker in water	0.50	│
TB 192	0.91	│ │
Petrolatum Texaco no. 1234	1.04	│
Treseal	1.06	│
10% Brunolinum plantarium in water	1.92	│
0.8% Antimucin in water	2.11	│
Untreated control	2.16	│

$S_m = 0.1567$ ($n_2 = 12$)

The mean damage was for all experimental trees (315 trees) on the portion of the panel tapped in July, September and November 1967:

July: 0.40
September: 3.29
November: 0.37

Exp. 19 (1967): *black thread control*

Clone BD 5, planted in 1943, tapped monthly periodic on second bark renewal at about 90 cm above union. The 4 treatments were distributed over 2 tapping tasks, which were tapped by different tappers. Each plot (one line of trees) contained on the average 30 trees. Treseal was applied twice a week and the other treatments once a week during the tapping months of June, August, October and the first half of December. Results were evaluated mid December 1967 and separate evaluations were made on the portions tapped during the above months. The figures are means of the evaluations made on the August and October portions.

Treatments	Number of plots in		Mean black thread damage	
	task 1	task 2	1965/'66	1967
1. 1% captafol + 0.1% Ortho sticker in water	0	4	2.24	0.83
2. Treseal	2	2	1.85	1.85
3. 0.8% Antimucin in water	4	0	2.09	2.13
4. Untreated control	3	1	2.11	3.60

Treatment No.	Adjusted estimates of 1967 damage	Scheffé test at 10% level	*t* values for treatment differences		
			1	3	2
1	1.09	|	x		
3	1.67	| |	2.30	x	
2	2.29	|	9.28	2.56	x
4	3.35		11.15	12.88	5.51

Scheffé criterion at 10% level: $\sqrt{3F_{10}^{3}} = 2.86$

The mean damage was for all experimental trees (471 trees) on the portions tapped in different months:

June: 0 (approximately)
Aug.: 1.73
Oct.: 2.37
Dec.: 0.38 (first half of the month)

Exp. 20 (1967): *black thread control*

Clone BD 5, planted in 1943, tapped monthly periodic on second bark renewal at about 90 cm above union. The 4 treatments were distributed over 2 tapping tasks, which were tapped by different tappers. Each plot (one line of trees) contained on the average 37 trees. Treseal was applied twice a week and the other treatments once a week during the tapping months of July, September and November. Results were evaluated at the beginning of December and separate evaluations were made on the portions tapped during the above months. The figures are means of the evaluations made on the July and September portions.

Treatments	Number of plots in		Mean black thread damage	
	task 1	task 2	1965/'66	1967
1. 0.8% captafol + 0.1% Ortho sticker in water	0	4	1.89	1.04
2. Treseal	2	2	1.92	1.74
3. 0.6% Antimucin in water	4	0	2.24	2.64
4. Untreated control	2	2	1.94	2.85

Treatment No.	Adjusted estimates of 1967 damage	Scheffé test at 10% level	*t* values for treatment differences		
			1	2	3
1	1.29		x		
2	1.78		4.55	x	
3	2.31		7.41	4.72	x
4	2.88		14.89	11.56	5.08

Scheffé criterion at 10% level: $\sqrt{3F_{10}^{3}} = 2.86$

The mean damage was for all experimental trees (592 trees) on the portions tapped in different months:

July: 0.29
Sep.: 3.73
Nov.: 0.18

Exp. 21 (1967): *black thread control*

Clone BD 5, planted in 1948, tapped alternate daily on first renewal at approximately 50 cm above union. Randomized block trial with 4 blocks, 5 plots per block and ± 11 trees per plot. The average 1965/'66 black thread damage amounted to 2.52 (range between treatment means: 0.13). The fungicides were applied every fourth day (after 2 tappings) on rest days from June through the middle of December. The results were evaluated mid november 1967 and again in March 1968.

Treatments	Mean 1967 damage, evaluated in:			
	Nov. '67	Duncan test at 5% level	Mar. '68	Duncan test at 5% level
0.8% captafol + 0.1% Ortho sticker in water	1.42		0.90	
Treseal	2.18		1.79	
0.6% Antimucin in water	3.12		2.64	
0.5% Mycocide latex in water	3.74		3.16	
Untreated control	4.07		3.35	
S_m (for $n_2 = 12$)	0.3342		0.4054	

Exp. 22 (1968/'69): *black thread control, yield stimulation and bark proliferation*

Clone BD 5, planted in 1945, tapped alternate daily on second bark renewal at 75–100 cm above union. Replicated tree plot design with 34 trees per treatment. Average 1966/'67 black thread damage amounted to 0.74 (range between treatment means: 0.05). Average pretreatment yield over 50 tappings during March/May 1968 was 28.8 g dry rubber per tree and per tapping (range between treatment means: 0.7). The treatments were applied once a week from the beginning of June '68 through January '69. The black thread control results were evaluated mid January '69. The yields of cup coagulum were statistically analysed and are given in the table as a percentage of the Treseal treatment (no. 1). The yield figures refer to an 8½ month' period (99 tappings during June '68 to January '69).

Treatments

1. Treseal
2. 0.25% 2,4-D (butyl ester) in Treseal
3. 0.5 % 2,4-D (dimethylamine salt) + 1% captafol
4. 0.5 % 2,4-D (sodium salt) + 1% captafol
5. 1 % captafol + 0.1% Ortho sticker
6. 0.5 % 2,4-D (dimethylamine salt) + 1% captafol + 0.1% Ortho sticker
7. 0.5 % 2,4-D (dimethylamine salt) + 1% captafol + 0.5% Ortho sticker
8. 0.5 % 2,4-D (dimethylamine salt) + 1% captafol + 1% XRD-24
9. 0.5 % 2,4-D (dimethylamine salt) + 1% captafol + 10% XRD-24
10. 0.25% 2,4-D (dimethylamine salt) + 1% captafol + 0.5% Ortho sticker
11. 0.25% 2,4-D (sodium salt) + 1% captafol + 0.5% Ortho sticker

Note: To all aqueous treatments (nos. 3–11) 0.05% Panelred was added.

Results

Mean yield of cup coagulum over 8½ months, expressed as a percentage of Treseal-treatment (No. 1)

Treatm. No.	Yield	Duncan test at 5% level			
9	169	|			
2	157	|	|		
7	150		|	|	
3	149		|	|	
8	149		|	|	
6	146		|	|	|
11	139			|	|
10	137			|	|
4	133				|
5	113				
1	100				
S_m = (for n_2 = 330)	4.5286				

Percentage deformation of treated panels

Treatm. No.	Deformation
2	99
9	83
4	32
3	27
6	26
8	26
7	15
10	5
11	5
1	0
5	0

Yield of Treseal treatment as g dry rubber per tree and per tapping (No. 1): 41.8

The experiment was inconclusive with regards the significance of differences in black thread damage among treatments (F calc./F theor. < 1).

Exp. 23 (1968/'69): *black thread control yield stimulation and bark proliferation*

This experiment had the same layout and treatments as Exp. 22 and was situated in the same planting. However, tapping was on the other days. There were 28 trees per treatment. Average 1966/'67 black thread damage amounted to 1.46 (range between treatment means: 0.03). Average pretreatment yield over 50 tappings during March/May 1968 was 29.5 g dry rubber per tree and per tapping (range between treatment means: 0.4). For other data see Exp. 22.

Results

Mean 1968 black thread damage

Treatm. No.	Damage	Duncan test at 5% level			
5	0.59	|			
3	1.00	|	|		
10	1.00	|	|		
11	1.07	|	|	|	
7	1.41	|	|	|	|
4	1.93		|	|	|
6	1.96		|	|	|
8	2.12		|	|	|
2	2.20		|	|	|
9	2.30			|	|
1	2.59				|
S_m = (for n_2 = 270)	0.394				

Mean yield of cup coagulum over 8½ months, expressed as percentage of Treseal-treatment (No. 1)

Treatm. No.	Yield	Duncan test at 5% level			
2	171	|			
9	158	|	|		
8	156	|	|		
6	155	|	|		
3	152		|		
4	151		|		
7	150		|		
10	142		|	|	
11	131			|	
5	111				|
1	100				|
S_m =	5.799				

Yield of Treseal treatment as g dry rubber per tree and per tapping: 44.1

Percentage deformation of treated panels		Degree of bleeding (scale 0–3)	
Treatm. No.	Deformation	Treatm. No.	Bleeding
2	100	2	1.96
9	82	9	1.53
8	40	6	0.55
6	33	8	0.50
4	29	4	0.50
3	28	3	0.41
7	27	7	0.29
11	7	10	0.04
10	5	11	0
1	0	1	0
5	0	5	0

Exp. 25 (1968): *black thread control*

Clone BD 5, planted in 1948, tapped monthly periodic on first bark renewal at about 95 cm above union. This randomized block trial was carried out in one tapping task. Each plot (one line of trees) contained on the average 34 experimental trees. Treseal was applied twice a week and the other treatments once a week during the tapping months of June, August and October. Panelred (0.05%) and Ortho sticker (0.1%) were added to all captafol suspensions (treatments 1 to 4). Results were evaluated mid November 1968 and separate evaluations were made on the portions tapped during the above months. The figures are means of the evaluations made on the August and October portions.

Treatments	Number of plots		Mean black thread damage	
	block 1	block 2	1966/'67	1968
3. 1% captafol	1	1	1.47	0.70
2. 0.5% captafol	1	1	1.48	0.78
4. 2% captafol	1	1	1.80	0.88
5. Treseal	2	1	1.45	0.97
1. 0.25% captafol	1	1	1.33	1.82

There was no evidence for significant differences between treatments at a 5% basis; the means of treatments 2 to 5 were about the same. However, the difference between Treatment 1 and 2 were about the same. However, the difference between Treatment 1 and 2 (the lowest and second lowest captafol concentration) had a t_4 value of 2.56 (with critical level 0.07).

The mean damage was for all experimental trees (376 trees) on the portions tapped in different months:

Jun.: 0.12
Aug.: 1.27
Oct.: 0.77

Exp. 26 (1968): *black thread control*

Clone BD 5, planted in 1948, tapped monthly periodic on first bark renewal at about 90 cm above union. This randomized block trial was carried out in one tapping task. Each plot (one line of trees) contained on the average 17 experimental trees. Treseal was applied twice a week and the other treatments once a week during the tapping months of June, August and October. Panelred was added in 0.05% concentration to all suspensions of captafol (treatments 1 to 5). Results were evaluated in the second half of November 1968 and separate evaluations were made on the portions tapped during the above months. The figures are means of the evaluations made on the August and October portions.

Treatments	Number of plots		Mean black thread damage	
	block 1	block 2	1966/'67	1968
4. 1% captafol + 1% XRD-24	1	1	1.56	0.10
2. 1% captafol + 0.1% Ortho sticker	1	1	1.69	0.15
3. 1% captafol + 0.5% Ortho sticker	1	1	1.66	0.22
1. 1% captafol	1	1	1.49	0.26
5. 1% captafol + 10% XRD-24	1	1	1.61	0.38
6. Treseal	2	2	1.56	1.13

Treatment No.	Adjusted estimates of 1968 damage	Scheffé test at 10% level	*t* values for treatment differences				
			2	4	3	1	5
2	0.21	|	x				
4	0.23	|	0.16	x			
3	0.29	|	0.62	0.45	x		
1	0.42	|	1.51	1.39	0.91	x	
5	0.49	|	2.02	1.87	1.41	0.47	x
6	1.26		8.69	8.66	8.04	7.00	6.49

Scheffé criterion at 10% level: $\sqrt{5F^5_6} = 3.94$

The mean damage was for all experimental trees (242 trees) on the portions tapped in different months:

Jun.: 0.01
Aug.: 0.71
Oct.: 0.26

Exp. 27 (1968): *black thread control*

Clone BD 5, planted in 1948, tapped monthly periodic on first bark renewal at about 90 cm above union. This randomized block trial was carried out in one tapping task. Each plot (one line of trees) contained on the average 13 experimental trees. The fungicides were applied once a week in treatments 1 and 3, and twice a week in treatments 2, 4 and 5 during the tapping months of June, August and October. Panelred (0.05%) and Ortho sticker (0.1%) were added to all suspensions of captafol (treatments 1 to 4). Results were evaluated mid November 1968 and separate evaluations were made on the portions tapped during the above months. The figures are means of the evaluations made on the August and October portions.

Treatments	Number of plots			Mean black thread damage	
	block 1	block 2	block 3	1966/'67	1968
4. 0.5% captafol (2×)	1	1	1	1.78	0.09
2. 1% captafol (2×)	1	1	1	1.51	0.13
3. 0.5% captafol (1×)	1	1	1	1.32	0.15
1. 1% captafol (1×)	1	1	1	1.75	0.53
5. Treseal (2×)	2	1	1	1.82	0.85

Treatment No.	Adjusted estimates of 1968 damage	Scheffé test at 10% level	*t* values for treatment differences			
			4	2	3	1
4	0.04		x			
2	0.24		0.82	x		
3	0.37		1.13	0.58	x	
1	0.50		2.18	1.11	0.45	x
5	0.81		3.76	2.18	1.35	1.47

Scheffé criterion at 10% level: $\sqrt{4F^4_8} = 3.35$

The mean damage was for all experimental trees (202 trees) on the portions tapped in different months:

Jun.: 0.04
Aug.: 0.55
Oct.: 0.19

Exp. 35 (1969/'70): *black thread control, yield stimulation and bark proliferation*

Clone BD 5, planted in 1945, tapped alternate daily. Tapping was on a high cut in virgin bark when the experiment started, 18 cm above firstly renewed bark on the average. Replicated tree plot design with 27 trees per treatment. Average 1967/'68 black thread damage amounted to 1.56 (range between treatment means: 0.09). Average girth at approximately 120 cm above union was 82.3 cm (range between treatment means: 0.6). Average pretreatment yield over 38 tappings (April–June 1969) amounted to 28.0 g dry rubber per tree and per tapping (range between treatment means: 1.3). Care was taken that the different positions of the tapping cut above the renewed bark were equally distributed over the treatments (6.2.4.). The products were applied weekly above the cut from the beginning of July 1969 through January 1971; however, no applications were made from mid January 1970 through March to give the trees some rest during the driest months. At the beginning of the experiment a stock of twenty times concentrated mixtures were made up and stored at 10–15°C; from these concentrates the dilutions ready for use were prepared monthly. These first batches of concentrates were used through January 1970. New batches were made up in April, which stock lasted to October whereafter the stock was renewed once again. The black thread damage on the 1969 panel was evaluated in December 1969 and evaluated once more 6 months later (June 1970). The damage done to the 1970 panel was evaluated in January 1971. The dry rubber production of each tree was determined monthly. The degree of abnormal bark renewal because of stimulation was evaluated on the 1969 panel in December of that year and for the 1970 panel in January 1971.

Treatments

1. Treseal
2. 0.25% 2,4-D (butyl ester) in Treseal
3. 1% captafol + 0.1% Ortho sticker in water
4. 0.5% 2,4-D (isooctyl ester) + 1% captafol + 0.1% Ortho sticker in water
5. 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide + 0.01% Sterox in water.
6. 0.1% 2,4-D (isooctyl ester) + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide + 0.01% Sterox in water.
7. 0.25% 2,4-D (isooctyl ester) + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide 0.005% Sterox in water.
8. 0.5% 2,4-D (isooctyl ester) + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide in water.
9. 1% 2,4-D (isooctyl ester) + 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide in water.
10. 1% Antimucin + 5% Mobilcer Q + 0.05% Panelred in water.

1969 black thread damage, evaluated: December 1969			1969 black thread damage, evaluated: June 1970			1970 black thread damage, evaluated January 1971		
Treatment No.	Damage	Duncan test at 5% level	Treatment No.	Damage	Duncan test at 5% level	Treatment No.	Damage	Duncan test at 5% level
5	1.93		8	2.00		8	0	
3	2.00		7	2.11		6	0	
6	2.28		3	2.11		5	0.07	
7	2.57		5	2.15		7	0.11	
4	2.63		4	2.15		1	0.13	
8	2.63		9	2.20		4	0.15	
9	2.72		6	2.39		3	0.22	
1	2.94		1	3.07		9	0.26	
10	4.07		10	3.89		10	1.83	
2	4.46		2	4.37		2	2.31	
S_m (for $n_2 = 234$)	0.3012			0.3197			0.1813	

Yield over 6-month periods as percentage of Treseal treatment with Duncan test at 5% level

Jul–Dec. 1969		Jan–Jun. 1970		Jul–Dec. 1970		Total (Jul '69–Dec. '70)	
Treatm. No.	Yield	Treatm. No.	Yield	Treatm. No.	Yield	Treatm. No.	Yield
2	163.7	2	182.4	2	193.6	2	178.7
9	130.8	9	131.4	9	133.6	9	131.9
4	119.2	4	117.8	4	120.0	4	118.5
8	117.7	8	115.5	7	119.6	7	116.6
7	115.2	7	115.0	6	114.3	8	115.6
6	108.8	6	108.5	8	111.4	6	110.6
3	106.0	3	107.7	3	108.2	3	107.2
10	105.5	10	104.8	10	103.1	10	104.5
5	102.1	5	103.2	5	100.2	5	101.7
1	100.0	1	100.0	1	100.0	1	100.0
$S_m =$ (for $n_2 = 234$)	5.2851		7.3996		8.7072		6.4270
Yield of Treseal treatment as g dry rubber per tree and per tapping (No. 1):	32.9		20.3		26.4		26.4

Percentage bark proliferation in stimulated treatments

Treatment No.	on 1969 panel	on 1970 panel
6	0	0
7	2	1
4	3	7
8	16	5
9	39	44
2	99	100

Exp. 37 (1969): *black thread control*

Clone BD 5, planted in 1945, tapped alternate daily on second bark renewal at about 125 cm above union. Randomized block trial with 4 blocks, 7 plots per block and 13 trees per plot. Average pretreatment damage (1968) amounted to 1.01 (range between treatment means: 0.08). Fungicides were applied weekly from July 30 through December. The same dilutions ready for use – made up at the beginning of the experiment – were used throughout the trial. Results were evaluated in May 1970.

Treatments	1970 damage	Duncan test at 5% level
1. 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide + 0.01% Sterox in water	1.42	
2. Treseal	1.88	
3. 1% captafol (Difolatan-4-flowable) in water	2.08	
4. 1% captafol + 0.1% Ortho sticker in water	2.25	
5. 1% captafol + 0.1% Ortho sticker + 1% yellow iron oxide + 0.1% 2,4-D (isooctyl ester) + 0.01% Sterox in water	2.51	
6. 1% Antimucin in water	3.58	
7. 1% Antimucin + 5% Mobilcer Q in water	3.80	

$S_m = 0.3179$ ($n_2 = 18$)

Exp. 41 (1970): *black thread control*

Clone BD 5, planted in 1948, tapped alternate daily on first bark renewal at about 100 cm above union. Replicated tree plot design with 20 trees per treatment and with 2 treatments. The 40 experimental trees were treated with 1% captafol + 1% yellow iron oxide + 0.1% Ortho sticker + 0.01% Sterox in water. Application was after each tapping in Treatment 2 and once a week in Treatment 1 and all other trees in this planting. The applications were made from July through November. Data on pretreatment damage, done during a number of consecutive years, were collected.

Treatments	Pretreatment black thread damage in:						1970 black thread damage
	1964	1965	1966	1967	1968	1969	
1. captafol applied once a week	2.2	2.1	2.4	2.0	1.1	2.1	0
2. captafol applied every other day	2.2	2.0	2.4	1.9	1.1	1.7	0

Exp. 42 (1970/'71): *yield stimulation*

Clone Har 1, planted in 1960, tapped alternate daily on virgin bark on first panel at 25–40 cm above union. Replicated tree plot design with 30 trees per treatment. Average pretreatment yield over 31 tappings (October/November 1970) was 63.7 g dry rubber per tree and per tapping (range between treatment means: 2.8.). The average girth of the trees amounted to 78.1 cm (range between treatment means: 0.9). Treatments 11 and 12 were applied once only. On December 2, Treatment 11 was scraped at normal depth; however, in Treatment 12, only the outer dead cork was removed (with a steel brush). The products were applied the following day in these 2 treatments. All above-cut treatments were applied weekly during December and January. The yield figures refer to the first 3, the following 8 and last 3 tappings in December, and to the first 13 and last 3 tappings for January.

Treatments	g mixture used per 10 trees and per 2 months
11. B.C.–2″ band, scraped deep – 1 % ethephon + 0.2 % Panelred	54
10. A.C. – 0.25 % 2,4-D (butyl ester) in Treseal	181
12. B.C. – 2″ band, steel brushed – 1 % ethephon + 0.2 % Panelred	47
4. A.C. – 0.25 % ethephon + 1 % yellow captafol mix.	198
5. A.C. – 0.25 % 2,4-D (isooctyl ester) + 1 % yellow captafol mix.	204
8. A.C. – 0.25 % 2,4-D (dimethylamine salt) + 0.1 % Panelred	205
6. A.C. – 0.25 % 2,4-D (dimethylamine salt) + 1 % yellow captafol mix.	196
3. A.C. – 0.025 % ethephon + 1 % yellow captafol mix.	209
2. A.C. – 2 % yellow captafol mix.	149
7. A.C. – 0.25 % ethephon + 0.1 % Panelred	188
1. Untreated control	–
9. A.C. – Treseal	167

The above treatments were in aqueous media, except for treatments 9 and 10, which were in or with Treseal. The 1 % yellow captafol mix. contained: 1.25 % Difolatan 80 WP + 1 % yellow iron oxide + 0.1 % Ortho sticker + 0.01 % Sterox; in the case of Treatment 2, twice this strength was tested.

Results: yields as percentage of untreated control

Treatm. No.	Total Dec + Jan.	Duncan test at 5% level	Tappings in December				Tappings in Jan.		
			first 3	next 8	last 3	total 14	first 13	last 3	total 16
11	135		201	147	147	158	119	107	116
10	114		101	114	121	113	114	119	115
12	112		115	116	112	115	111	108	110
4	110		105	112	106	109	111	112	111
5	109		103	111	104	108	109	113	110
8	109		102	111	113	109	109	110	109
6	108		108	110	106	109	108	106	108
3	104		102	104	100	103	104	107	104
2	102		101	104	99	102	103	101	102
7	100		100	102	100	101	99	99	99
1	100		100	100	100	100	100	100	100
9	99		97	100	103	100	98	98	98
S_m = (for n_2 = 319)	2.392		2.945	2.904	4.008	2.529	2.886	3.637	2.867
Yield of untreated control as g dry rubber per tree and per tapping	66.0		62.4	65.8	62.3	64.3	67.8	66.1	67.5

Exp. 43 (1970/'71): *yield stimulation*

Clone BD 5, planted in 1945, tapped alternate daily on second renewal (4-year-old bark) at about 75 cm above union. Replicated tree plot design with 23 trees per treatment. The trees of abandoned Exp. 39 (not in Appendix; described in detail under 5.5.8.3.) were used with a different distribution of trees over treatments. Average pretreatment yield over 73 tappings was 41.6 g dry rubber per tree and per tapping during June to October 1970 (range between treatment means: 0.2), over 16 tappings in October '70: 43.4 g (range between treatment means: 0.6), and over 15 tappings in November: 44.6 g (range between treatment means: 4.7). The below-cut treatments 2 and 9 were applied once only. Scraping was on December 2/3 and application the next day. Treatment 2 was scraped at normal depth; in Treatment 9, only the outer cork layers were removed (with a steel brush). All above-cut treatments were applied weekly during December and January. In the table with results, at first the total yields over December + January are given as was done for Exp. 42.

Treatments:	g mixture used per 10 trees and per 2 months
2. B.C. – 2" band scraped deep – 1% ethephon + 0.2% Panelred	69
10. A.C. – 0.25% 2,4-D (butyl ester) in Treseal	263
9. B.C. – 2" band, steel brushed – 1% ethephon + 0.2% Panelred	72
6. A.C. – 0.25% 2,4-D (dimethylamine salt) + 1% yellow captafol mix.	263
4. A.C. – 0.25% ethephon + 1% yellow captafol mix.	287
7. A.C. – 0.25% ethephon + 0.1% Panelred	285
8. A.C. – 0.25% 2,4-D (dimethylamine salt) + 0.1% Panelred	283
5. A.C. – 0.25% 2,4-D (isooctyl ester) + 1% yellow captafol mix.	275
1. Untreated control	–
3. A.C. – 0.025% ethephon + 1% yellow captafol mix.	263

The above treatments were in aqueous media, except for treatment 10, which was with Treseal. The 1% yellow captafol mix. contained: 1.25% Difolatan 80 WP + 1% yellow iron oxide + 0.1% Ortho sticker + 0.01% Sterox.

Results: yield as percentage of untreated control

Treatm. No.	Total Dec. + Jan.	Duncan test at 5% level	Tappings in Dec. first 3	Tappings in Dec. next 7½	Tappings in Dec. last 3	Tappings in Jan. first 12	Tappings in Jan. last 3
2	151		227	163	141	133	120
10	147		114	137	147	160	160
9	135		183	142	127	124	119
6	129		114	130	141	132	120
4	118		111	113	111	124	128
7	117		107	117	117	119	120
8	115		102	116	113	119	114
5	111		101	115	116	113	104
1	100		100	100	100	100	100
3	97		95	99	95	97	97
S_m = (for n_2 = 198)	4.236		5.739	5.484	5.440	4.686	4.608
Yield of untreated control as g dry rubber per tree and per tapping	43.8		47.2	45.6	48.1	41.4	41.4

Exp. 44 (1971): *yield stimulation*

Clone Har 1, planted in 1960, tapped alternate daily on virgin bark on first panel at 10–25 cm above union. Replicated tree plot design with 30 trees per treatment. The trees of abandoned Exp. 42 were used and the distribution of trees over 12 treatments was the same. The yield over 3 tappings in March 1971 (see Exp. 42) can be considered as pretreatment yields, which amounted to 51.6 g dry rubber per tree and per tapping (range between treatment means: 7.2). For girth measurements see also Exp. 42. The trees of treatments 9, 11 and 12 were scraped on March 22 and application of products was the following day. Scraping and application were repeated for treatments 11 and 12 two months later (May 20 and 22). At that time Treatment 9 was split in two treatments with 15 trees each; the products were applied to the same portions of the guide lines treated two months before, which portions were now located 2 inches above and 2 inches below the tapping cut (in 9a application was without re-scraping and in 9b after re-scraping). Treatment 2 was also split in two new treatments with 15 trees each; these new guide line treatments were scraped for the first time on May 20 and application was 2 days later. All above-cut treatments were applied weekly for 4 months, except for Treatment 2, which lasted only 2 months. The yields were determined over 15 tappings in March/April, over 15 tappings in April/May, over 14 tappings in May/June and over 14 tappings in June/July.

Treatments	g mixture used per 10 trees and per 2 months
11. B.C. – 2″ band – 1% ethephon + 0.2% Panelred	69
9b. G.L. – 4 × 2″ (A,B,C,D) – scraped and treated for second time with 5% ethephon in palm oil	13
12. B.C. – 2″ band – 1% ethephon + 1% yellow captafol mix.	63
9. G.L. – 2 × 4″ (A,B) – scraped and treated for first time with 5% ethephon in palm oil	13
6. A.C. – 1% ethephon in palm oil	235
5. A.C. – 1% ethephon + 20% wax emulsion + 1% yellow captafol mix.	280
2a. G.L. – 4 × 2″ (A,B,C,D) – scraped and treated for first time with 5% ethephon in palm oil	11
4. A.C. – 1% ethephon + 10% glycol + 1% yellow captafol mix.	282
2b. G.L. – 3 × 6″ (A,C,D) – scraped and treated for first time with 5% ethephon in palm oil	23
3. A.C. – 1% ethephon + 1% yellow captafol mix.	284
9a. G.L. – 4 × 2″ (A, B, C, D) – not re-scraped and treated for second time with 5% ethephon in palm oil	11
10. A.C. – 0.25% 2,4-D (butyl ester) in Treseal	197
8. A.C. – 1% 2,4-D (dimethylamine salt) + 1% yellow captafol mix.	285
7. A.C. – 0.25% 2,4-D (dimethylamine salt) + 1% yellow captafol mix.	287
2. A.C. – 0.25% ethephon + 1% yellow captafol mix.	286
1. Untreated control	–

Treatments were in aqueous media when not in palm oil or Treseal. The 1% yellow captafol mix. contained: 1,25% Difolatan 80 WP + 1% yellow iron oxide + 0.1% Ortho sticker + 0.01% Sterox. Glycol was propylene glycol. The wax emulsion used was Mobilcer Q.

Results: Yield as percentage of untreated control

Treatment No.	Per period of 15 tappings (1 month)				
	first	second	third	fourth	mean of 2–4 months
11	179	132	160	112	144
9b	–	–	(162)	(125)	(143)
12	158	124	166	118	140
9	168	122	–	–	139
6	156	141	138	123	139
5	145	142	136	126	137
2a	–	–	(158)	(113)	(134)
4	129	135	137	123	131
2b	–	–	(149)	(114)	(131)
3	121	136	137	124	130
9a	–	–	(138)	(117)	(127)
10	121	125	127	117	123
8	123	126	123	103	119
7	113	119	119	113	116
2	110	113	–	–	112
1	100	100	100	100	100
yield of untreated control as g dry rubber per tree and per tapping	42.6	50.8	49.4	54.1	49.1

The figures in between brackets apply to 15 trees only; all others refer to 30 trees.

Separate statistical analyses were made on comparable groups of 15 trees per treatment for 2-months stimulation periods as otherwise the results of the split treatments (2a, 2b, 9a, 9b) could not be incorporated in the analyses.

Yield as percentage of untreated control (Group I of 15 trees)

Treatment No.	First 2 months	Duncan test at 5% level	Treatment no.	Last 2 months	Duncan test at 5% level
6	159		12	144	
5	154		6	135	
9	151		2a	134	
11	150		5	133	
12	146		11	131	
3	135		3	129	
4	134		9a	127	
8	131		10	125	
10	131		4	125	
2	122		7	114	
7	118		8	106	
1	100		1	100	
S_m = (for n_2 = 154)	7.055			6.254	

Yield as percentage of untreated control (Group II of 15 trees)

Treatment No.	First 2 months	Duncan test at 5% level	Treatment No.	Last 2 months	Duncan test at 5% level
11	157		9b	143	
6	137		11	139	
9	135		12	138	
5	134		4	134	
12	133		3	131	
4	130		2b	131	
3	125		5	129	
8	119		6	125	
10	116		8	120	
7	115		10	119	
2	102		7	117	
1	100		1	100	
S_m = (for n_2 = 154)	5.780			6.433	

Exp. 45 (1971): *yield stimulation*

Clone BD 5, planted in 1945, tapped alternate daily on first (possibly second) renewal at about 100 cm above union. Replicated tree plot design with 27 trees per treatment. The trees of abandoned Exp. 35 were used and the same distribution of trees over 10 treatments was maintained. The average pretreatment yield over 38 tappings (April–June 1969) for Exp. 35 amounted to 28.0 g dry rubber per tree and per tapping (range between treatment means: 1.3). Application of treatments in Exp. 35 was terminated in January 1971. Two months later, the average yield over 3 tappings was 29.2 g per tapping (range between treatments mean: 3.6) for all experimental trees, with the exception of the 27 trees which were treated with 0.25% 2,4-D in Treseal in old Exp. 35. The yield of these 27 trees was still considerably higher and amounted to 39.8 g per tapping, which should be contributed to a very long-lasting after-effect of this treatment; in Exp. 45 these 27 trees received the same treatment. The above data indicate that the trees of all other old treatments were of a fairly comparable yield level in March. For girth figures see old Exp. 35. The below-cut and guide line treatments were scraped for the first time on March 24/25, 1971, and for the second time on May 23/24. Application of products was 2 days later. The above-cut applications were made weekly from March 26/27 through July 9/10. About half the number of trees of treatments 2 and 10 received a different treatment after 2 months, which new treatments are denoted 2b and 10b. This could be done quite easily as the experiment essentially consisted of two experiments, one located in the A farm (with 14 trees per treatment) and the other in the B farm (with 13 trees per treatment). Pretreatment data were of the same level between treatment means in each farm. The yields were determined every 30 days (after 15 tappings). Because of split treatments, separate statistical analyses were made of the figures collected on each farm.

Treatments	g mixture used per 10 trees and per 2 months
4. A.C. – 2.5% ethephon + 0.1% Panelred	281
8. A.C. – 1% ethephon in palm oil	232
10b. B.C. – 2" band – 10% ethephon in palm oil	38
2b. G.L. – 3 × 6" (A,C,D) – 5% ethephon in palm oil	22
7. A.C. – 1% ethephon + 20% wax emulsion + 1% yellow captafol mix.	300
6. A.C. – 1% ethephon + 10% glycol + 1% yellow captafol mix.	300
5. A.C. – 1% ethephon + 1% yellow captafol mix.	300
3. A.C. – 1% ethephon + 0.1% Panelred	302
2. G.L. – 2 × 4" (A,B) – 5% ethephon in palm oil	11
9. A.C. – 0.25% 2,4-D (butyl ester) in Treseal	229
10. B.C. – 2" band – 1% ethephon + 0.2% Panelred	43
1. Untreated control	–

Treatments were in aqueous media when not in palm oil or Treseal. The 1% yellow captafol mix. contained: 1.25% Difolatan 80 WP + 1% yellow iron oxide + 0.1% Ortho sticker + 0.01% Sterox. Glycol was propylene glycol. The wax emulsion was Mobilcer Q. The bark in below-cut and guide line treatments was normally scraped before application of products.

Results: Yield as percentage of untreated control

Treatment No.	Per period of 15 tappings (1 month)				
	first	second	third	fourth	mean of 2–4 months
4	292	340	299	248	290
8	226	310	311	236	268
10b	–	–	(389)	(173)	(267)
2b	–	–	(361)	(156)	(245)
7	219	266	250	221	237
6	222	262	258	204	234
5	192	231	239	195	213
3	191	226	218	186	204
2	(223)	(154)	(247)	(145)	(193)
9	166	199	185	170	179
10	(155)	(134)	(192)	(130)	(154)
1	100	100	100	100	100
Yield of untreated control as g dry rubber per tree and per tapping	19.4	17.2	23.0	26.3	21.5

The figures in between brackets apply to 13–14 trees only; all others refer to 27 trees.

Separate statistical analyses were made on the figures collected in the A farm (14 trees per treatment) and those in the B farm (13 trees per treatment), which analyses were applied to 2-months stimulation periods. As can be seen, treatments were the same in the A farm during the entire period of 4 months and also the same for the first 2 months on the B farm; however, because of splitting of treatments, treatments 2 and 10 do not exist during the last 2 months in the B farm as they were replaced by the new treatments 2b and 10b.

Yield as percentage of untreated control in A farm

Treatment No.	First 2 months	Duncan test at 5% level	Treatment No.	Last 2 months	Duncan test at 5% level
4	332		4	277	
8	257		8	273	
7	234		7	211	
6	224		6	203	
3	200		2	195	
5	194		5	193	
2	190		9	185	
9	184		3	181	
10	145		10	161	
1	100		1	100	
S_m = (for n_2 = 117)	10.709			11.475	

Yield as percentage of untreated control in B farm

Treatment No.	First 2 months	Duncan test at 5% level	Treatment No.	Last 2 months	Duncan test at 5% level
4	293		8	269	
8	275		10b	267	
6	262		4	266	
7	250		7	260	
5	231		6	259	
3	216		2b	245	
2	203		5	240	
9	178		3	223	
10	150		9	168	
1	100		1	100	
S_m = (for n_2 = 108)	15.039			17.448	

Exp. 46 (1971): *yield stimulation*

Clone Har 1, planted in 1960, tapped alternate daily on virgin bark on first panel at 10–25 cm above union. Replicated tree plot design with 32 trees per treatment. Average pretreatment yield over 4 tappings in March 1971 was 50 g dry rubber per tree and per tapping for all treatments. The treatments were applied once only, except for Treatment 2, which was applied weekly. The below-cut and guide line treatments were scraped on March 30; application of products was on April 1. Yields were recorded for 2 months (April and May); they were also determined over shorter periods (first 3 tappings in April; the month of April; the month of May). There were 15 tappings per month.

Treatments	g mixture used per 10 trees and per 2 months
5. B.C. – 2″ band – 10 % ethephon in palm oil	52.2
4. B.C. – 2″ band – 1 % ethephon + 1 % yellow captafol mix.	60.0
7. G.L. – 2 × 4″ (C,D) – 5 % ethephon in palm oil	±16.1
3. B.C. – 2″ band – 1 % ethephon + 0.2 % Panelred	40.9
6. G.L. – 2 × 4″ (A,B) – 5 % ethephon in palm oil	±16.1
8. G.L. – 2 × 4″ (A,D) – 5 % ethephon in palm oil	±16.1
2. A.C. – 0.25 % 2,4-D (butyl ester) in Treseal	237.2
10. G.L. – 2 × 4″ (A,D) – 5 % ethephon + 1 % yellow captafol mix.	15.6
9. G.L. – 1 × 4″ (A) – 5 % ethephon in palm oil	±8.1
1. Untreated control	–

Treatments were in aqueous media when not in palm oil or Treseal. The 1 % yellow captafol mix. contained: 1.25 % Difolatan 80 WP + 1 % yellow iron oxide + 0.1 % Ortho sticker + 0.01 % Sterox. The bark in below-cut and guide line treatments was normally scraped before application of products.

Results: yield as percentage of untreated control

Treatment No.	Total of April + May	Duncan test at 5 % level	First 3 tappings of April	Total of April	Total of May
5	159		255	188	129
4	144		166	158	129
7	141		187	155	126
3	140		161	154	125
6	132		179	145	118
8	131		175	145	118
2	127		97	121	133
10	118		135	126	110
9	109		122	113	105
1	100		100	100	100
S_m = (for n_2 = 279)	3.585		4.932	4.106	3.612
Yield of untreated control as g dry rubber per tree and per tapping	55.4		50.0	56.1	54.6

Exp. 47 (1971): *yield stimulation*

Clone BD 5, planted in 1945, tapped alternate daily on second bark renewal at about 75 cm above union. Replicated tree plot design with 19 trees per treatment. Average pretreatment yield over 9 tappings in May 1971 was 20.7 g dry rubber per tree and per tapping (range between treatment means: 0.2). The treatments were applied once only. The scraping operations were carried out on June 3 and the products applied one or two days later. Yields were recorded from June 5/6 to July 3/4 (23 tappings). They were also separately determined for the first 9 and last 14 tappings.

Treatments	g mixture used per 10 trees and per 2 months
2. B.C. – 2″ band – 10% ethephon in palm oil	68.3
7. G.L. – 3 × 4″ (A,C,D) – 10% ethephon in palm oil	14.6
5. G.L. – 3 × 6″ (A,C,D) – 5% ethephon in palm oil	18.5
3. G.L. – 3 × 2″ (A,C,D) – 5% ethephon in palm oil	9.5
4. G.L. – 3 × 4″ (A,C,D) – 5% ethephon in palm oil	12.3
6. G.L. – 3 × 4″ (A,C,D) – 2.5% ethephon in palm oil	12.5
9. G.L. – 1 × 6″ (C) – 5% ethephon in palm oil	7.5
10. G.L. – 1 × 6″ (D) – 5% ethephon in palm oil	5.2
8. G.L. – 1 × 6″ (A) – 5% ethephon in palm oil	6.0
11. G.L. – 3 × 4″ (A,C,D) – 2,5% 2,4-D (butyl ester) in palm oil	12.7
1. Untreated control	–

The bark in below-cut and guide line treatments was normally scraped before application of products.

Results: yield as percentage of untreated control with Duncan test at 5% level

Treatm. No.	Total 23 tappings	Treatm. No.	First 14 tappings	Treatm. No.	Last 9 tappings
2	217	2	253	2	161
7	169	7	196	5	131
5	161	5	180	3	131
3	151	3	165	7	128
4	141	4	159	6	115
6	137	6	151	4	114
9	119	9	125	9	110
10	116	10	125	10	104
8	113	8	124	11	103
11	107	11	109	1	100
1	100	1	100	8	97
S_m = (for n_2 = 180)	7.444		8.564		6.542
Yield of untreated control as g dry rubber per tree and per tapping	45.9		45.4		46.7

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Former employments:

N.V. Philips-Duphar, 's-Graveland, the Netherlands (1953–1960)
Agricultural Research Station, Manokwari, West-New-Guinea (1960–1962)
Firestone Plantations Company, Harbel, Liberia (1963–1971)
Agricultural University, Wageningen, the Netherlands (1971–1972)

Present employment:

Merck Sharp & Dohme Nederland N.V., Haarlem, the Netherlands