INTERNATIONAL RUBBER CONFERENCE

Proceedings of the

International Rubber Conference

"75 Years of Rubber Research in Sri Lanka"

Colombo, 17-19 September, 1984.

VOL. 1

PART (1)

RUBBER RESEARCH INSTITUTE OF SRI LANKA
AGALAWATTA.

PROCEEDINGS OF THE INTERNATIONAL RUBBER CONFERENCE
SRI LANKA

Vol. 1 (Part I) 1984

CONTENTS

PAGE

OPENING SESSION

75 YEARS OF RESEARCH AND WHAT OF THE FUTURE

By

MAJOR MONTAGUE JAYEWICKREME

(Hon Minister of Plantation Industries)

Mr Chairman, Hon Ministers, Your Excellencies, Ladies & Gentlemen,

It gives me great pleasure to be here, when the Rubber Research Institute of Sri Lanka is celebrating 75 years of activity in this country. I understand that the Rubber Research Institute of Malaysia is celebrating 60 years of research in that country, next year, 1985. That makes us 16 years senior in this act – this is quite fitting, as rubber was introduced into South East Asia, through Ceylon in 1876. This was the origin of the massive natural rubber (NR) industry in South East Asia, which supplied practically all the rubber requirements of the world until about 1950. Then came synthetic rubber (SR).

Research into rubber production and processing started in Ceylon in 1909, when a Committee consisting of British plantation interests was formed, to provide advisory and research backing for the rapidly growing rubber planting industry, the planted area of which had then reached an extent of about 200,000 acres. An Analytical Chemist was the first scientific officer appointed, and his assignment was to study the coagulation of latex. The original scheme was reorganized in 1913, when it was named the Rubber Research Scheme, and the Government of Ceylon agreed to provide 60 percent of its expenses, the balance coming from private subscribers.

The Rubber Research Ordinance was incorporated on 30 August, 1930, and the offices and laboratories of the scheme were moved to its present Headquarters, at Dartonfield, Agalawatte in 1934, which makes this year, also the Golden Jubilee Year of the move to Agalawatte. The Rubber Research Scheme was named the Rubber Research Institute of Ceylon in 1951, by an amendment to the original Act of Parliament.

That is the history of our Institute in chronological terms. However, in terms of research achievement, the RRI of Sri Lanka has contributed a great deal to the knowledge on the crop. We were the pioneers in *Hevea* breeding, starting these studies in the mid – 1930s, and we appear to be holding our own still, as it was brought to my notice recently that three of our clones had come out at the top of the list in international clone trials planted in Indonesia, Malaysia and Thailand. We were also the first to replant rubber on a large scale with Government aided schemes. In fact, all NR producing countries use our replanting ordinance as a basic guideline for their parallel schemes. Our nursery techniques, tapping systems, critical use of fertilizers and stimulants are highly developed. The RRI of Sri Lanka has always had a special flair for plant pathology, and you will forgive me if I say that we still set the pace in this branch of science. Coming to production, it is universally accepted that, in crepe rubber, we produce the world's purest and highest quality of NR. This is an enviable record of achievement, when you consider that we produce about 3 percent of the world's NR and are now only the sixth largest producer, following Malaysia, Indonesia, Thailand, India and China.

Having said that, let me hasten to add that, rubber research is very much an international effort. I was only trying to say here, that Sri Lanka is contributing its fair share to the pool of knowledge, and that my Government is giving and will give every encouragement to the industry. The Director of my Institute is always fond of telling me that " we have a small but elite set of research workers, and given the funds and infra-structure, we can match the best in the world". Well, you have 3 days in which to match each others wits, and see who is doing what.

I take this opportunity of welcoming all the foreign guests from some 15 countries. Science has no barriers and unlike in any other branch of human endeavour, scientists are always willing to discuss their work and their achievements are judged mainly by their publications. This Conference I trust, will give you the opportunity to pool your knowledge, discuss your work, critically assess it and pass down to the industry some important new ideas that can be used immediately, to enhance the uses of rubber and increase its world market price.

I must say that I am disappointed with the present prices – frankly, I expected NR prices to be much higher at this time. I should like to discuss the matter of prices with the foreign experts who are here today and I look forward to this when I have the oppor tunity of meeting you individually, later on.

The message I wish to leave with you is that rubber is a crop that has always survived and thrived on the outcome of research. We went through crises in the 1950s, 1960s, and early 1970s, and it was always research and development (R & D) that came to the rescue of the crop. I have no doubt that research will find a way again. However, let us take stock over the next 3 days and think afresh – that is what research is all about. Let us get away from the hackneyed targets :

Improve efficiency and reduce COP by producing better clones,

Improve yields by better nutrition and disease control,

Devise better exploitation methods and stimulants,

Improve grading and packing.

We know all this and its your bread and butter, but think afresh. Think of the fundamentals, set goals, try to achieve them *e.g.* I was told that, theoretically it has been found that rubber trees can produce upwards of 9000 lb per acre per year. That's what I am thinking about – remember the rice breeders, they went into the basics, produced a shorter rice plant, with less leaves, but each leaf set at such an angle to the sun, it was more efficient. Result : the short, so called " miracle " varieties of paddy. Another thing I am personally interested in is mass propagation – tissue culture. Why do you require a 2 or 3 part tree ? Grow a tree on its own stock. Surely that will give you higher yields. Do some basic research, don't be bogged down in applied work alone. Let your mind wander, give it full reign. Don't be frightened to think. You are paid to do just that.

I am not a scientist, but I am a very successful rubber planter. I implement every innovation suggested by the RRI immediately on my plantation, and I must say I have got good results, but what I want here are large jumps in the contribution of science, the World Bank is fond of the term "quantum jumps". So may I suggest today to all of you, think big, aim for the moon, and if you reach the top of the tree, then you aren't doing too badly. And while you are about it, do not forget marketing – if we can persuade each of our Chinese friends to buy one pair of rubber shoes per year. Talk of all the perfumes of Arabia – all the rubber in the world would not meet the demand.

With that thought, I wish this Conference every success. You are here to discuss the advances in rubber research, papers will be read and I hope, discussed, criticised and reassessed by you ; because research becomes useful only when it is skilfully criticized by those who have to use it in the field. So the planters here have a special duty, learn and critically assess. To the foreign participants I say : please don't go away soon after the Conference. Stay and see something of our country. Whatever you may have heard and read, Sri Lanka is beautiful by any standard, and the Sri Lankans are a warm, friendly people, whose hospitality is legendary. Stay and enjoy some of it, you are amongst friends.

I have great pleasure now in declaring this Conference open.

SCOPE OF THE CONFERENCE

By

D. M. FERNANDO
(Assistant Director, Rubber Research Institute, Sri Lanka)

Mr Chairman, distinguished visitors, and fellow delegates – It is indeed a pleasure and a privilege to express on behalf of the Rubber Research Institute of Sri Lanka, and all those present here our sincere thanks and appreciation to the Hon'ble Minister of Plantation Industries, Major Montague Jayewickreme, for declaring open this International Rubber Conference. His graciously delivered and thought provoking address will no doubt set the stage and tone of what promises to be an exciting Conference week.

On the background of our present accent on development, it is necessary for us in the natural rubber industry of Sri Lanka to communicate closely and effectively with modern science ; this can only be achieved by presenting our research findings to the International elastomer field. Therefore, this Conference is vital for us to exploit the versatality of natural rubber as a source of gainful and increasing employment throughout Asia with an almost unlimited capacity for adjustment to consumer requirements. The dynamism of our local industry has been supported recently by the World Bank and this Conference seeks in some measure to re-inforce this revitalizing of our industry.

The Conference will present 86 papers on a range of topics from *Hevea* breeding and selection to speciality products from abroad.

A very important feature of this Conference will be the guest lectures. Our guest speaker Tan Sri Dr B. C. Sekhar is known too well to all of us, in achievement and prestige, and needs no further introduction. Now an acknowledged leader in the field of natural rubber we are singularly privileged to be present at this perhaps his valedictory lecture in his present position. He will no doubt fly even higher in his country's service as is his due. We have fully appreciated Tan Sri Dr Sekhar's address at our last Conference in 1976 when he increased the morale of the industry in this country and no one can forget the role played by him. When the threat of synthetic competition tended to undermine confidence in a product which is expected now to be of vital and ever increasing importance to the developing countries.

We also have as guest speaker Dr Upatissa Pethiyagoda, now FAO consultant, formerly Director of the Coconut Research Institute, and earlier Head, Plant Physiology Department of the Tea Research Institute. His record as the first person to get a first class Hons. degree in Botany from the Colombo University is remembered by many to this day. His earlier work on the propagation of tea and later administrative efforts in expansion of coconut nurseries has finally ended in improvement of the date palm in the Middle East. It is perhaps appropriate that he should present an interesting and over-all view in this forum on all three major crops of Sri Lanka.

Of the individual sessions we are starting with views of two Heads of our important State Plantation Sectors. I am sure the papers presented by Mr P. R. Seneviratne, Secretary, Ministry of Janatha Estates Development Board and Mr Ranjan Wijeratne, Secretary, Ministry of Sri Lanka State Plantations Corporation in addition to his duties as Chairman, Agricultural Development Board, will serve to increase and clarify the rapport between research and industry.

We will have two concurrent sessions, one in the Main Assembly Hall covering Biology and a second in Committee Room A covering Rubber Chemistry and Technology.

We will start the Biology Sessions with our contribution on crown budding followed by papers from Malaysia, China and India. This would be followed by breeding and selection where our substantial genotype/environment studies are followed by an interesting contribution from China on planting rubber at high altitude followed by our studies on the clone PB 86. In exploitation and yield stimulation, India, Malaysia and the Ivory Coast will present their views. On the second day Thailand and India will offer their views on fertilizer use and India, Brazil, Malaysia and Indonesia will supplement our paper on a bark disease.

Of particular interest in Session 6 is the study of climate and yield where we have been ably assisted by the Universities of Colombo and Reading to bring the latest computer facilities to this study for the first time. Prof. Domroes of Mainz University, West Germany, then presents a geographer's point of view on the subject.

We have been particularly interested in the difficult subject of research extension to the vital smallholder section of our industry and we are very grateful to Dr Raja Badrul Shah Kobat of Malaysia and Dr. Colin Barlow, whom I think we can say we share with Australia, for their contributions.

Contributions on root diseases are mostly from the Ivory Coast and Sri Lanka where *Rigidoporus* has been worked on for a long time. May we take this opportunity to thank the IRCA for fourteen promising SALB resistant clones received in 1983.

In Session 9 on soil management we have again assistance from the University of Western Australia and from Malaysia.

An exclusively Sri Lankan team presents the vital aspect of marketing as perhaps no country wishes to publicize what they are doing in this field.

On the economics of rubber we are very pleased to meet our old friends Dr Dan Etherington, Dr Peter Allen from UK, Prof. Ulrich Smit from the Netherlands and Dr Suan Tan from the World Bank.

The Planter's view closing the Biological Session will, I am sure be profitable to all.

In the Session on Rubber Chemistry and Technology we would be covering bleaching agents and crepe manufacture in the first Session. Indian and Malaysian views would be expressed in the second Session on special rubbers. Again UK, India and Australia join us on the chemical modifications of NR. On technology and analysis we are pleased to have Dr Mullins from UNIDO, and Dr Fuller and Dr Derham from MRPRA in UK and Dr Bradbury from Australia. Our guest researcher from China, Dr Li Jiu Long will present work on compounding and ageing properties. Dr Barnard from MRPRA, UK, will doubtless have something substantial to offer. Prof. Gerald Scott of Aston, who has trained most of our technologists, will speak on antioxidants, joined by Dr Loo from RRIM and Dr Loadman from MRPRA. Latex properties will see contributions from India and Malaysia. The newly stressed facets of energy and pollution are discussed mainly by local scientists.

May we thank our overseas visitors and contributors for their esteemed presence, and trust they will find time to see something of this entrancing Island during their stay. We also thank the staff and Organizing Committee very sincerely for their untiring efforts and trust that the interaction between producer and consumer, research and extension, will be substantially increased during and after these 3 days.

FUTURE OF PLANTATIONS AS I SEE IT

By

P. R. SENEVIRATNE

(Secretary, Ministry of Janatha Estates Development Board and Chairman, Janatha Estates Development Board, Sri Lanka)

Hon Minister, Mr Chairman, distinguished guests and friends — it is a pleasure for me to participate on this occasion, which marks the 75th Anniversary of the Rubber Research Institute. I am conscious of the fact that this august assembly, which Dr Ossie Peries has asked me to address on the subject of the " Future of the Plantation Industry " comprises some of the most prominent Scientists and top Administrators, in whose hands the destiny of the rubber industry actually rests. As the JEDB, inter-alia, is at present responsible for the management of about 27,000 hectares under rubber cultivation, my comments, although general in nature, will, to a large extent, be influenced by the practical knowledge gleaned from, and problems experienced in Sri Lanka. I know our overseas visitors will bear with me in this respect.

It is useful, when attempting a prediction for the future of the rubber industry, to look at the past to see what lessons the history of the industry has to teach us.

Although rubber was introduced to Sri Lanka in the year 1876, I find that the first recorded export of rubber from Ceylon (as this country was then called), was in the year 1900. A total quantity of 4 tons of rubber was exported and the total extent under rubber cultivation was 1,750 acres. In 70 years, the extent of land under cultivation of rubber had increased to 560,000 acres, with a production level of 160,000 tonnes. An interesting bit of information is that, at the beginning of the century, rubber, fetched as much as £ 417 per ton at the London market – the equivalent of 4·20 Sri Lankan Rupees per kilogramme. The enormous profits realised, of course, were enjoyed by the Rubber Companies at the time. By contrast, the 1983 London average of 75·05 new pence, which is equivalent to Rs. 27 appears to be disappointingly low. During the depression of the 1930's, however, I find that rubber was sold in London at £ 2·12 per ton, which is equivalent of -/22 Sri Lankan Cents per kilogramme – a low figure indeed !

From the above bare facts, we have a very brief sketch of the growth and fluctuating fortunes of the rubber industry.

Reverting to the theme given to me, which is the " Future of the Plantation (Rubber) Industry as I see it ", I propose to arrange my remarks under two broad heads, namely, the prospects of there being a continuing and growing demand for rubber in the future, and the future of rubber production in the years to come.

As far as the demand for natural rubber is concerned, the industry has encountered progressive competition from the synthetic product, and it would be interesting to examine, in slightly closer detail, the impact that the production of synthetic rubber has had on the demand for natural rubber.

Upto 1940, natural rubber held undisputed sway and supplied 100% of the needs of all industries. In 1940, 1·127 m tonnes of natural rubber were produced and this quantity was found insufficient to meet the demand. Large scale synthetic rubber industries emerged when supplies of natural rubber were found inadequate and when supply lines were blocked as a result of World War II.

By the year 1950, the total demand for rubber had risen to 2·339 m tonnes, of which quantity, the natural product could contribute only 75%, that is, 1·750 m tonnes. Synthetic rubber gained progressively in proportion to the natural product in meeting the total demand, basically due to the inability of natural rubber to keep pace with the demand. The proportion of natural to synthetic has stabilized at around 30%, of the total requirement, from 1975 to date, and even so, the entire production of natural rubber is absorbed. The escalation of oil prices in 1973/74 also worked to the advantage of natural rubber. The share of natural rubber is expected to rise to about 40%. At the present rate of development, the forecast for output of natural rubber is that, production will increase from 4 m tonnes to around 8 m tonnes by the year 1990.

Let us examine the respective positions of natural rubber and its synthetic rival, as can be gleaned from the experience of the past four decades.

(a) A manufacturer's choice between natural and synthetic depends on three main considerations, namely, suitability for specified purposes, the price and availability. I shall elaborate on these aspects as we go on.

(b) Natural rubber lost ground mainly due to problems of availability.

(c) The two products are not altogether inter-changeable, that is, natural rubber cannot be said to be identical in all respects to its synthetic rivals and vice-versa. Consequently, there are manufacturing industries, which prefer one product to the other, on account of certain particular properties, which are peculiar to that product.

(d) Natural rubber, generally speaking, has more desirable properties, such as greater elasticity, greater resilience, and better resistance to tearing and cutting.

(e) Research is underway in order to eliminate some of the less desirable characteristics, which are found in natural rubber.

(f) The physical properties of natural rubber render it superior for use in the production of items such as : aeroplane tyres, truck tyres, surgical gloves, adhesives and similar items.

Approximately 60% of the natural rubber production goes into the manufacture of tyres. The proportions vary according to various extraneous factors, but in the manufacture of large tyres for heavy duty trucks and aeroplanes, etc., natural rubber is the product, which is exclusively used. There is, therefore, no doubt that the demand for our full production of natural rubber will continue. This demand will naturally grow in pace with the growth of industries, such as automobile, engineering and domestic appliances and similar consumer goods, etc. In other words, the demand for rubber keeps pace with the progress of the general development in industry.

We, as producers, however, must take meaningful steps to consolidate and to improve our position.

The first problem that has to be faced in this connection, is availability – that is, ensuring production at adequate levels.

According to forecasts by authoritative and knowledgeable sources, the global output of natural rubber is expected to increase to 5 m tonnes by 1985 and to 5·80 m tonnes by 1990. The corresponding demand for the natural product is assessed at 6·7 m tonnes in 1985, and 8 m tonnes in 1990. It will be seen, therefore, that, unless natural rubber production can be increased at an accelerated rate, it will not be able to keep pace with the increase in demand.

In practice, what measures can we adopt towards increasing productivity ? I venture to suggest a few.

Replanting

A major reason retarding an increase in production is the failure to sustain a systematic and consistent long term replanting programme. We may examine the reasons for this although it will be appreciated that some of these may be peculiar to Sri Lanka.

(a) The loss of income during the first 7 – 8 years when the rubber is immature. This more seriously affects the smallholder who depends on his plot of rubber for his and his family's subsistence. Some 30% of the rubber in Sri Lanka is in plots of less than 10 acres.

Malaysia, which has a larger proportion of smallholders, has introduced livestock rearing. This problem should be faced squarely by countries like Sri Lanka, and positive measures taken. In fact, this aspect may be of universal interest, because about 70% of all rubber land in the world belongs to smallholders.

(b) Inadequate producer margins on trade, coupled with a subsidy which does not adequately cover the outlay in replanting, as in the case of Sri Lanka.

(c) The procedures as regards application, inspection and supply of planting materials and the concomitant delay in respect of subsidy instalments, are certainly far too tedious for the smallholders. These may be simplified with advantage.

(d) Another factor, which requires reappraisal is the replanting cycle. In order to produce natural rubber at a competitive price and to cushion the effect of heavy wage increases, it may be worth examining the economics of :—

(i) reducing the replanting cycle, and

(ii) intensifying the harvest, thus increasing the overall annual yield per hectare and production.

Thailand replants 3.3% of its rubber annually, while Sri Lanka's general rate is 3%.

We, in Sri Lanka, have found PB 86 a reliable clone which has stood the test of time from the thirties. Several newer and fancier clones failed to come upto expectations. The white latex of PB 86 is also ideal for latex crepes for which Sri Lanka is noted.

However, the yield potential of PB 86 is inadequate to meet the demands of the future market in respect of quantity or unit price. Our Research Institute has fortunately evo lved clones with a superior yield potential and comparable latex properties and these new clones will be used in our future replanting programmes.

As for Sri Lanka, the State owns only 30% of the land under rubber cultivation and 70% remains under private ownership. It will be a difficult task to persuade the smallholders who own 56% of the estates below 100 acres in extent to change from PB 86 bud grafts to these new clones.

Salvaging and upgrading the present crop potential

It is estimated that approximately 5,000 tonnes of cup lumps and tree lace are not harvested in the small holdings of Sri Lanka, as the selling price is not attractive. Perhaps, the same position may exist in other rubber producing countries as well. If the Government can give a subsidy of, say, Rs. 2 per kg, to block rubber manufacturers, they would be induced to purchase the cup lumps and tree latex at an attractive price for conversion into block rubber, thus making a meaningful addition to the country's national and foreign exchange earnings.

Similarly, it would also be possible to encourage the purchase and conversion of the No. 3 & 4 RSS into block rubber by the same method.

Smallholders — replanting

Replanting of small blocks containing a few acres each is a slow process. Though the Government pays a subsidy towards the cost of the replanting exercise, the owner-family is often faced with a substantial reduction in or even total loss of its regular income or livelihood during the period of immaturity of the replanted block.

Smallholdings — general

Of the 7 million hectares of rubber in the world, smallholders own 70%. In the two giant producer-countries, Malaysia and Indonesia, small holdings amount to 70% and 80% respectively. In Thailand, with a total of 1·5 m hectares, 95% of this extent is with smallholders.

The growth rate of natural rubber production is affected to a great degree by the large extent of small holdings ; mainly in two ways —

(a) the unit yields from small holdings are generally only about one half of the yields produced by the estate sector, and

(b) a very large proportion of the available crop from smallholders is manufactured into low grade rubber.

If natural rubber is to meet the progressively increasing demand, which is anticipated to go up to 8 m tonnes by 1990, it is of utmost importance to stimulate and motivate the small holdings sector. The long term objective should be to evolve a modern, organised group of well-informed rubber farmers who will obtain the optimum yield – in quantity, as well as in quality from their holdings. In this respect, Malaysia has set a worthy example with her Malaysian Rubber Development Corporation, which operates several factories turning out the highest quality SMR from smallholders' latex. To a more modest extent the Rubber Manufacturing Corporation of Sri Lanka has also shown in practice that the highest quality block rubber, and sheet rubber, can be produced from smallholders' latex.

Malaysia, with some 500,000 smallholders, has taken other steps to have organised and modern management made available to smallholders, such as by the setting up of Development Centres, which cater for 20 – 40 smallholders each. Other producer countries like Sri Lanka would profit by following Malaysia's example.

So far, my remarks were in the main, confined to the **quantitative** aspects of production. But, let us briefly examine the **qualitative** aspect, as well.

Consistency in standard, is as important a factor, as regularity in supply. It has also been found that the standard and mode of packing has a material bearing on the marketing and price prospects. For example, hydraulic pressing of rubber sheets into bales makes for easy handling, saving in freight and in the avoidance of mould formation. It has been found that RSS 1 in pressed bales of 33·3 kg polypacks obtains a higher price than the normally made-up bales.

TSR in the form of block rubber is the most convenient type for industrial purposes. It will, therefore, be necessary for countries such as Sri Lanka to consider switching over to block rubber manufacture as an alternative to crepe and RSS. As far as Sri Lanka is concerned, some 40% of the output is made into crepes, which sell at a premium over TSR.

There is a role that research has to play in the future of the industry. It is impossible to pursue development of the rubber industry without advice and guidance from a competent, and well equipped research institute which should be provided with adequate resources of personnel and finances.

The improvement of the genetic quality of planting material, the technology of manufacture and, above all, the study of the particular problems of smallholders and provision of practical advice and assistance to this Sector, are some of the areas in which the investment of effort and finances will reap rich dividends.

Finally, the future of the industry would be also dependent on the successful marketing policies that are adopted.

As previously stated, there is growth potential in the demand for natural rubber and this is expected to outstrip supplies. It must not be forgotten, however, that natural rubber has to guard against being supplemented or rendered obsolescent, by synthetic rubber which has certain tactical and practical advantages. For example, natural rubber has to be conveyed over long distances by land and sea from the producer to the consumer. On the other hand, with synthetic rubber, vertical integration between production and consumption is possible. Further, in the case of synthetics, the purchasing country does not need to spend her foreign exchange and all the "value added" remains within the country.

It is, therefore, vitally necessary to have a comprehensive marketing network providing service as regards promotion at prospective sales centres, and market-intelligence to producers. One cannot help feeling that at present there is inadequate contact between the producer of natural rubber and the consumer. This is demonstrated by one recent example. When Malaysia had to give up its production of sole crepe due to labour problems last year, Sri Lanka, which was the logical alternative source of supply, did not benefit from the void thereby created. We can only surmise that the buyers have turned to industrial sole crepe made in their countries with our thin crepe.

An efficient marketing service should enable the producer to maximise the resources from all available sources of rubber production.

The world recession had its impact on rubber prices as well and this industry suffered a set-back in 1981 and 1982. However, the situation is now changing. In 1983, car sales increased by 17·3% in the UK and the production of cars in the USA rose by 21%. Japan hopes to import extra rubber in 1984. The prospects definitely appear favourable.

It is clear, therefore, that the natural rubber industry has a bright future, the demand for it being a barometer of general world development and prosperity. But, we producers have to work, and work hard, to maintain the industry at the highest levels of production, both quantity and quality-wise.

In conclusion, I think it is most appropriate to quote Dr B. C. Sekhar, who is present among us today, in this context. Dr Sekhar says, "If ever natural rubber loses out to synthetics and other substitutes, it will not be due to competition from synthetics, but because natural rubber production has not expanded fast enough". This in a nutshell is the future of our Rubber Industry as I see it.

Thank you for your patient hearing.

WHERE DO WE GO FROM HERE

By

R. WIJERATNE
(*Secretary, Ministry of Sri Lanka State Plantations Corporation and Chairman, Sri Lanka State Plantations Corporation*)

Hon Minister of Plantation Industries, Director, RRI of Sri Lanka distinguished guests, Ladies and Gentlemen.

I consider it an honour to have been called upon to address you today at this International Conference, which is held to coincide with the 75th Anniversary of the establishment of the Rubber Research Institute of Sri Lanka.

Basically I am a tea planter, but I am venturing to let you have some of my observations in regard to rubber, as I have had to deal with rubber production and marketing as a Director of an Agency House during the 7 year period before nationalisation and now as Head of one of the State Corporations. I have had the occasion to visit rubber plantations and I am in the process of brushing up my knowledge on rubber. So you will have to bear with me if I tend to flounder in my observations.

Rubber's beginnings as a plantation crop in Sri Lanka derived from the fact that the main crop of the time ran into difficulties. The weak prices for tea which prevailed in the early years of this century, up to 1907, made some planters search for a more profitable crop. Rubber which was just beginning to be demanded in large quantities by the industrial countries, was fetching attractive prices. From just 1,750 acres in 1900, the Sri Lanka acreage increased to some 150,000 acres by 1907, and to 630,000 acres by 1939, and 642,200 acres by 1960. The yield in 1939 is recorded as 209 pounds per acre. The unit export price recorded at that time was 0·42 cts per pound. The Sri Lanka rubber boom though dramatic, was not so overwhelming as the contemporaneous upsurge of the Malayan Rubber Industry. Two factors — *i.e.* the relative scarcity of good uncultivated land for rubber, as most suitable land was already under tea and the revival of tea prices after 1907 limited the expansion of the Sri Lanka's rubber industry. Nevertheless, growth was rapid, and by 1913 rubber earned about three fourth as much foreign exchange as tea. In 1917 with the industry enjoying war inflated prices, it actually surpassed tea for the first time in export value. Because of rubber's 5 to 7 year gestation period, it was not until about 1917, that the full fruits of the first extensive plantings began to be realised.

Despite this new production, we would have collected the general excess demand in the world market if the war had not intervened. At the end of the war however, demand fell off and prices plummetted to less than half of the 1919 level. In 1922, the Stevenson restrictions came into effect and in the following year prices rallied. Despite the Stevenson Scheme, Sri Lanka's acreage continued to rise and the acreage output and export rose steadily throughout the decade of the twenties, and by 1929, Sri Lanka claimed about a 10th of the world acreage, ranking a poor third behind Malaya and Netherlands East Indies. Prices however hit a peak in 1935, and then began to decline. This particular fall in prices was indicative of the failure of the Stevenson Scheme to prevent world over supply. But, soon the world depression set in and demand dropped catastrophically. The bottom fell out from the world market. The sensitivity of the Sri Lanka rubber industries at the depression of the 1930's was extreme. Prices sank and Sri Lanka's rubber proved to be an especially poor competitor in a tight market. Much of the country's acreage was already getting old. 40% of it had been planted before 1911. There are references in official documents that there was a considerable reduction in the output in the early 1930's.

According to the Director of Agriculture, some 40% of the tappable area was left untapped in 1932, about half of the workers who had been employed in 1929 had by then been laid off. By 1934, a new international output restriction went into effect, and prices began to recover. Soon after, a partial recovery of demand based partly on German re-armament and partly on the subsequent limited survival of civilian demands and upsurge of military needs elsewhere, set in and the path had improved further. By 1939, the rubber industry was back on the road to good health. In the following year it felt the beginnings of a new boom. Rubber has been much more of a smallholder's industry than tea. The economies of scale in the industry are evidently much smaller. Moreover, the location of good rubber land at the middle altitudes, closer to the bulk of the peasant population, than tea, made the crop appealing to smallholding peasants. So, from the early days of the industry in Sri Lanka smallholders have played a significant role. About 40% of Sri Lanka's rubber land in the 1930's were holdings of less than 100 acres.

Currently, the smallholders account for about 60% of the acreage. Rubber smallholders in Sri Lanka typically use the cultivation of the crop as a supplementary sideline, shifting their attentions from rubber to other agricultural or non-agricultural interests when rubber prices decline, and back to rubber when they rise. When they decide to tap they hire casual labour from the village and when they are not tapping, their trees stand almost completely unattended.

We have witnessed the Korean rubber boom, when prices escalated and producers virtually slaughter tapped the rubber in order to rake in high profits. With the end of the Korean boom, prices slumped to such levels, that the China/Sri Lanka rice for rubber pact had to be signed, against stiff opposition from powerful nations. The rubber/rice pact was in operation up to 2 years ago, and when the need to import rice diminished, rubber was allowed to be marketed freely. The rubber rice pact gave a breather to the rubber industry and much replanting was carried out during this period.

Rubber prices have been as elastic as the product, but has generally increased in line with wage increases over the years. It is a peculiar situation in that, one could state that end users of raw rubber appear to be keeping the industry going by pumping in sufficient oxygen to keep producers breathing and not collapsing. Sri Lanka rubber in recent years has become something of an enigma. Despite enthusiastic and widespread replanting, output has slumped. Only highly efficient producers will be able to expand or at least maintain export receipts by increasing output fast enough to compensate for price declines. Sri Lanka's output has stagnated and loud complaints are being heard about the depressed state of world markets.

We are living in a world of advanced technology. Technology which is improved on, virtually daily. In the field of rubber technology, we have seen the production of technically specified rubbers. The technically specified rubber concept is important in that it has altered the whole of the natural rubber industry. From the initial nucleus concept of having technical specifications for natural rubber, the raw rubber processing techniques were modified to produce crumbs of uniform quality. The packaging and shipping aspects were modernised.

The ever widening circle of influence of the technically specified rubber concept is now impacting on the preparation for shipment, marketing of latex concentrates and special rubbers. It is obvious that the specified rubber producing countries are the most highly industrialised countries, with sophisticated rubber product manufacturing industries. Natural rubber producing countries on the other hand are at the bottom, in respect of even rubber based industrialisation. We in this country have to follow the pattern of the end use of our raw materials, whether it means as natural rubber or as a technically specified rubber. We must learn to service the end users on the one hand and also encourage the establishment of rubber based manufacturing processes in this country. In the USA, the rubber products manufacturing industry is expected to increase its production value to around 20 billion US $. The main item of this rubber products industry in the United States is obviously tyres and inner tubes, which in 1975 was worth 6·9 billion US $.

The time has come for the RRI of Sri Lanka to list out its priorities. Firstly, I would like to see the RRI and the planting community getting closer to each other. I find that with years of research there is still apprehension in the minds of planters in the use of the RRIC clones. They are still planting clone PB 86. In my discussions with senior planters, I am advised that RRIC clone 100 is the most promising clone and should be widely used. Research must make it known very clearly to planters as replanting on a very large scale is contemplated under the Medium Term Investment Programme and I would hesitate to go ahead with clones that have a detrimental effect on the final product. Both in yield and in colour one has to determine a clone that will stand up to the requirements of the industry.

I would like to see better supervision of smallholder nurseries, *i.e.* nurseries that provide material for replanting of smallholdings. I would like to see in the field of manufacture, smallholder latex collected and processed in state factories.

In regard to processing, I would like to see the Research Institute applying itself to technologies that are already available and improving upon them, prevailing on investors in this country to export a value added product rather than continually export the raw product. We must move away from exporting the raw product that we have been used to. There have been inquiries in regard to centrifuging. We should go into these fields of activity vigorously if we are to survive as an industry. Today's wage claims to meet the rise in cost of living and other inflationary tendencies make it incumbent on producers to increase yields by planting high yielding proven clones, resorting to short re-planting cycles, in order to bring the unit cost of production down and also to going more and more into technically specified rubbers and to other forms of processing such as centrifuging, and manufacturing of end products. There are a whole host of end products such as mattresses, pillows, gloves, balloons, rubber bands, shoes etc. In the engineering trade, to name a few, engine mounts, fenders, tyres, tubes, seals etc. Such a wide range of products can be manufactured in this country and exported in competition with synthetic products. The State should encourage such investments with attractive incentives.

I understand that Malaysia has established the RRIM Technology Centre to promote natural rubber based industrialisation. This centre, I understand, gives advice on machinery and plant layout, training of management and operatives in both processing, fabrication techniques and quality control, product testing, sampling and testing plans to ensure product consistency. Why is Sri Lanka lagging behind ?

It would be imprudent for natural rubber producing countries to watch and wait helplessly, while development and technologies evolved elsewhere dictate the course, price and consumption of natural rubber. It would be opportune at this time to push ahead with this ultimate step of natural rubber based industrialisation ?

With those words, I wish to thank the Director RRI, and his officials for the excellent arrangements made for this International Conference and I hope all of you will deliberate and arrive at conclusions that will in the long-term enhance the profitability of this great industry.

THANK YOU.

INVITATION LECTURES

NATURAL RUBBER RESEARCH AND DEVELOPMENTS PAST PRESENT AND FUTURE

By

TAN SRI DR B. C. SEKHAR

(Chairman, Malaysian Rubber Research & Development Board)

ABSTRACT

This has been a long survey of the natural rubber industry. While considering its research contributions past and present, and in daring to outline possible future research, I have interwoven with the narration and assessment, some of the cogent forces and developments that took the industry along the routes it has traversed. Also feeling that research is not something like the casual growth of weeds, I felt it useful to consider the role of regional and international agencies that have contributed to the position of the rubber industry as it is today, and how it can contribute for its tomorrow.

In this review, then we have seen the coming of natural rubber to South and SE Asia, we have seen how it became an important raw material and in the process how it was buffetted by the price element. We also saw how individual attempts to restrict production and export failed, and how producers acting independently could not achieve price stability. The lessons were learnt and only in the 70s were we convinced of the real need for co-operative solutions. And this same spirit of reasonableness, and objectivity is also increasingly characterising the hitherto animistic struggle between SR and NR to corner the market. The foes of the past are the allies of the present and rather than vie with each other there is now room for cordial cooperation, each one knowing its strength and weakness and realising also their combined strength in new areas.

And during this first phase of research we saw the mechanical response of research activities to the simple demands for more rubber. Research was therefore largely amorphous and concerned only getting better trees and improving tapping methods. But the intervening wars and the birth and growth of the polymer industry had revolutionised research attitudes during the second phase of research. There were enormous advances on the technological front, and on the agro-biological levels there were refinements and clear objectives for research. By then governments and organisations realised that in a competitive world only the best would survive and no propping up can support an industry the magnitude of rubber. And in this survival, the rubber industry has proven its ability to overcome obstacles, seize opportunities for betterment, and plan ahead for further advancement. I am equally confident that it will continue to display this same vigour, strength and ingenuity but with one difference. The frontiers of knowledge have expanded so far ; the means available to understand them have equally increased. But there will always be a gap between what is known and unknown ; what is understood and what is to be understood ; what is to be done and what can be done. If these realities are accepted, then the challenges and opportunities facing the rubber researchers are no less for the future.

No commodity has faced the ravages of fluctuating prices, the challenges from analogous synthetic substitutes, the threat of devastating diseases, and unwelcome tariff protectionist policies as severely as Natural Rubber (NR). That it has withstood these challenges, and in the process become more resilient is a tribute not just for the inherent qualities of the commodity, but also for the great number of scientists who through their persistent research efforts, have placed it in a desirably dominant position among agricultural crops today. Its economic importance and even political and social significance in the producing countries are so crucial today that it will be a useful exercise to consider the growth of this crop, its present status and where it could and should move in the future.

In wishing to trace its hundred-year development and reflect on the impact of research achievements, past and present, and suggest directions for future research and developmental efforts, I wish more to dwell on the motives and forces that propelled research action and how national and international action have contributed to its present commanding position.

The need for rubber

Rubber did not make an impact on the world economy until the early twentieth century. Up to that time, the limited quantity of rubber that was required came exclusively from wild rubber, and mostly from its original home, the Amazons. The discovery of vulcanisation by Charles Goodyear and Thomas Hancock was the catalyst for the expansion in the use of natural rubber. Within a few years after this discovery, the demand began to outstrip the supply of crude natural rubber. The rapid increase in production up to about 1900 (Table 1) reflects the significance of the discovery of vulcanisation.

Table 1. *World production of rubber*

Year	Production (Tonnes)	Year	Production (Tonnes)
1830	25	1890	38 750
1840	150	1900	44 000
1850	750	1910	94 000
1860	6 000	1920	341 000
1870	8 000	1930	825 000
1880	9 900	1940	1 395 000

Other improvements in the treatment and processing of rubber increased its applications as in insulation of electric cables and wires. Dunlop's invention of the pneumatic tyre represents perhaps the turning point in this history of NR. The consequence of this development with those of the internal combustion engine and the battery is the explosiv surge in use of NR in the transportation sector. These developments had two immediate effects. First, Britain tried to make itself less dependent on the wild rubber, by seeking to establish the crop in her colonies. Secondly, the rapid growth of the automobile industry compelled the creating of a more stable and expanding source natural rubber supply. The foundations of a dominant plantation industry was thus laid.

Rubber comes to SE Asia

Henry Wickham is credited with the transportation in 1876 of some 70,000 rubber seeds from Brazil to Kew Gardens. Within the next few years, young seedlings were sent to Ceylon and *via* Ceylon to Singapore to be planted. However only some 20 years later did rubber trees come to commercial cultivation in Ceylon, Malaysia, and later in Indonesia. Much credit for this development is due to Ridley whose perseverance, conviction and persistence enabled *Hevea* to take a firm grip in Malaysian agriculture and inspired similar action elsewhere.

The British action with *Hevea* in Ceylon and Malaysia was followed closely by the Dutch in Indonesia and the French in Indo-China. Three factors which aided this spread of plantation rubber were the suitability of soil and climate, the availability of an abundant supply of labour, whether indigenous or recruited, to harvest the crop and the economic value of the crop.

In this early establishment and promotion of rubber cultivation until the beginning of the second world war, the initiative of large companies, later supported by governments, was instrumental in the large-scale cultivation of rubber. The success of this crop became so evident that by the 1940s, South and SE Asia had become the world's most lucrative supplier of rubber (Table 2).

Table 2. *Production of natural rubber in South and South East Asia 1900 — 1940*

Country	Year and production ('000 tonnes)				
	1900	1910	1920	1930	1940
Malaysia	104	6 313	170 000	449 400	544 300
Indonesia	—	2 724	75 522	240 921	537 465
Ceylon	—	1 698	39 532	75 602	88 413
Thailand	—	13	44	4 349	43 940
India	—	137	6 376	6 822	13 023
Indo-China	—	173	3 122	10 288	64 437
World	—	45 000	84 000	342 500	1 417 500

Rubber receives the first price shocks

Two features characterised this period. First, the rubber industry was buffetted by sharp price fluctuations. Before 1910 some 40,000 tonnes of wild rubber from Brazil and Africa satisfied world annual demands at a price of between 3 and 4 shillings a pound. There was a preliminary boom in 1906 when prices rose to 6 shillings per pound and by 1910 the price shot to over 12 shillings, giving the plantation industry tremendous impetus.

Within a year the price fell by more than half and during the first world war it hovered around 2 to 3 shillings a pound ; in 1921 the price fell below one shilling per pound. To avert this rapid decline and its economic consequence in Malaya and Ceylon the Stevenson Restriction Scheme went into effect, and by 1925 the price climbed to 4 shillings 8 pence. USA, the largest consumer of NR, began to seek its own sources of supply in reclaimed rubber and in plantations to be started in the Philippines, Liberia and even in Brazil. In the meanwhile, in the Dutch colonies, rubber production began to soar upwards. In the face of the rise of production, the Stevenson Scheme proved ineffective and in 1928 the scheme was abandoned. Actually, the downward trend in rubber consumption had started before 1928 but after that year when the depression in the USA cut sharply its demand for rubber the price plunged in catastrophic fashion to less than 2 pence in 1932. What the Stevenson Scheme could not do on its own was realised, and so in 1934 on a world basis, restriction of rubber production was reintroduced. This was the International Rubber Regulation Agreement (1934 – 1943) signed by UK, Netherlands, India, France and Siam. This concerted action proved more effective, and there appeared to be a price response reaching to about a shilling a pound.

The reasons for briefly narrating the price swings, the introduction of restriction schemes and the response of the largest consumer to such schemes are three-fold. First, to emphasise that from the inception, rubber had to face the vicissitudes of price extremes ; second, go-it-alone restriction schemes were ineffective ; and third, confrontation between producers and consumers did not deliver the desired objectives to their mutual advantage.

Early research mechanically responds to demand

The second distinguishing feature of the period was that the efforts and direction that went into research up to the 1920s was reflexively or mechanically responsive to the demand situation. No positive, co-ordinated or coherent direction was given to scientifically understand the tree, process the product or investigate its usage at the source of production. Whatever was done was the result of individual interest and enterprise. When in the early 1920s, it was beginning to dawn that there should be some concerted research action and development, the governments were persuaded to establish general agricultural research departments or institutes, and rubber became an important crop under scientific investigation. In fact, with the signing of the International Rubber Regulation Act of 1934, three additional rubber research institutes were established, *viz.* the British Rubber Producers' Research Association, the Rubber Stitching and the Institute Francais du Caoutchouc. At about this time the International Rubber Research Board was also established. The Rubber Research Institute of Malaya was already created in 1925. The former three, formed in consumer countries, were to carry out research on the use of rubber and extend its wider usage. The Rubber Research Institutes of Malaya, Ceylon, Indonesia and Indo-China were to largely research into the cultivation of the tree and the extraction of latex. The International Rubber Research Board was to encourage close liaison and co-ordination of work among the various research institutes. Thus research on an organised basis was given some footing and its importance for the future development of the industry was recognised by 1935.

First Phase of Natural Rubber Research

Research up to the 1940s may be conveniently called research of the past or the First Phase of Research. As hinted, this was almost entirely agricultural, and certainly concentrated on the exploitation of the crop as this was the most important requirement to obtain latex.

Exploitation

The earliest methods of tapping the trees in the plantations around 1889 were still the primitive axe-incision method used in Brazil. Naturally, this was found to have not only deleterious effects but also the collection of latex was inconvenient. And so research on tapping methods may be said to have commenced to overcome these shortcomings.

The origins reveal that various sharp implements, lighter and smaller than the axe, like chisels, pocket knives, etc were used and channels were made to control the latex flow to be collected in handy receptacles like cigarette tins. The incision method meant bringing the sharp edge of an implement to cut or wound the bark but not remove it. Two consequences were clear. One, the depth of the cut could not be controlled and two, inflicting several cuts not only caused massive wounding but also prevented the easy channelling of latex flow ; subsequent re-tapping was also difficult because of the bumpy wounds. Much of the initial efforts were met with frustration and in Malaya, Sir Frank Swettenham was said to have lost faith in the progress and questioned the potential value of the crop by disagreeing with Ridley's views. Ridley, however, was not discouraged and he continued with his experiments to improve the tapping methods on a scientific basis. He devised in 1897 the excision method by which a thin slice of the bark was removed. This system ensured a greater precision in tapping, allowed for easier subsequent tappings because it encouraged smoother bark renewal and, importantly, reduced the incidence of wounding.

From this herring-bone pattern of cuts invented by Ridley, many more attempts and variations were introduced. The questions uppermost in the mind of the researchers were not only to extract as much latex as possible, but also avoid wounding the tree and use labour effectively or economically. So the question of many cuts *versus* the V-cut and oblique or single cut were considered. It already became evident by the 1920s that multiple cuts did not proportionately yield more than a single cut and the heavier labour inputs at increased costs did not commend the former. Dutch scientists, too, who were working on the tapping systems, had engaged themselves with studies on the anatomy and physiology of *Hevea*. In this pursuit, Frey Wyssling's investigation on the mechanism of latex flow helped formulate tapping systems on a rational basis. By the 1940s the early tapping systems became more refined and evolved into the modern tapping systems characterised by a defined quantity of bark removal, reduced number and length of cuts and the frequency of tapping. Questions related to height of opening, direction and slope of cut, method of first tapping, depth of tapping, bark consumption, time of tapping, etc. were beginning to express themselves and attracted intellectual interest. Thus the simple objective of the first rough and ready method of extracting latex excited sophisticated scientific enquiries. And yet, even in this first phase of research, factors producing the latex, the mechanism of latex flow, the role of stimulation, and other systems of tapping like puncture, micro-X, mechanical or automated systems did not embed themselves in the researchers minds. All these developed rather rapidly during the Second Phase of Research.

Breeding and selection

In the First Phase of Research, another feature of importance was the experiments with breeding and selection, however straight-forward or simple the objectives may have then been. From the Wickham collection only twenty-two seedlings formed the nucleus of the Malaysian rubber industry. Some had already been successfully established in Ceylon and Bogor and these were fortified by the Dutch with their introduction of material in 1913 and 1915 into Indonesia. Yet these were a limited range of material, and necessarily early breeding and selection programmes were intensely in-bred, and still form the bulk of the planting materials used in the industry today.

The Wickham materials were extremely variable and in the 1920s were yielding less than 500 kg per hectare per year. It was thus felt that some form of breeding and selection had to be introduced to upgrade the base population. The Dutch effort to breed for improved material was started in 1919 at Algemene Vereniging Rubber Planters Oostkust Sumatra (AVROS), Medan, Sumatra. In 1927, similar efforts were attempted in Proefstation Voor Rubber, Java. A year later in 1928, the Rubber Research Institute of Malaya and the Prang Besar Research Station commenced their work. Vietnam followed suit in 1933 and Ceylon in 1939.

The early objective was aimed at mother tree selection on progenies derived from the base population. An assortment of primary clones were soon selected, and further improvement was made possible after Van Helten had successfully developed a vegetative grafting technique for rubber at Buitenzorg in 1915. These early efforts resulted in a prolification of rubber clones bearing names and symbols from these various research institutes and commercial agency houses. From Malaysia, the well-known clonal series are the RRIM series, the PB series and the CH series respectively bred by the Rubber Research Institute of Malaya, Prang Besar Research Station and the Chemara Research Station. The Rubber Research Institute of Ceylon produced the RRIC series, from Vietnam came the IRCI series and the TR series. Indonesia provided a number of prominent clones under the AVROS and PR series.

These experiments are recognised as the initial research efforts, where the basic aim was to improve yield ; this it did wondrously well by nearly threefold increases within two decades, and sixfold within five decades. The narrow objective of merely increasing yield and the limited material to work with did not allow the First Phase of Research to look into other features like early productivity, fast growing and vigorous clones to reduce the immaturity period, wind-fast and disease resistant clones, or clones suitable for a wide range of environment or climate. Nor was there a determined effort to introduce new materials from Brazil, although odd individuals like Dr P. J. S. Crammar made some attempts to widen the genetic base. All this was to come during the Second Phase of Research and more accurately after 1950.

But until then the research programmes of the past moved with narrow aims, responding mechanically to the call to increase yield but not giving much thought and time to secondary characteristics, and manufacturing technology. The basic aims in the phase were to increase the supply base and process the crop in a form amenable to quick transportation.

Neglect of agro-management

If on the two front lines of breeding and selection and exploitation of the crop, there was lack of clarity and long term considerations in objectives and organisation, then it would be true to say there was even less concern, and lesser facilities to research into other areas like disease and pest protection, manuring, and management, that is topics affecting density of planting, weeding, labour usage and so on. It may be safe to say, that until the 1920s very little serious thought was given to these aspects of research, although occasionally planters showed a cursory interest in them. But after the 1920s the agitation to found proper research institutes and request for research findings and advice on these matters became conspicuous and several suggestions were made and action taken.

First steps towards technological research

One other aspect needs to be noted during this First Phase of Research in the producing countries, particularly in Malaysia. Resulting from the increased usage of rubber, statements regarding the superiority of wild over cultivated rubber were not unheard of. Thus the much neglected aspect of technological research, that is in processing and packing the material came to the fore. Requests from brokers and manufacturers in the West for 'uniform quality', meant that producers puzzled over the best policy to meet consumer needs, since the latter could not clearly define their requirements. Basically it was related to the preparation of rubber. The views ranged from the avoidance of artificial aids and chemical additives, to use of alum to speed coagulation followed by smoke-drying, to use of acetic acid for coagulation. One firm was less concerned with chemical additives but more interested in a rubber with elasticity and free from dirt – the rudimentary call for visual gradation. But the first step had been taken and this was really the achievement of the Rubber Growers' Association. Its first publication of a thousand copies of *The Preparation of Plantation Rubber* in 1913 by S. Morgan was sold out within one month.

It was in this same year that the Rubber Growers' Association appointed a Standardisation Committee to propose a more accurate system for evaluating plantation rubber. But the subjective visual descriptions were not even challenged until 1950 when the first serious attempt at introducing Technically Classified Rubbers (TCR) was made.

Attitudes to research

We have so far been looking at the attitudes and developments of research in the producing countries up to about the 1940s. The research attitude and success noted have been described to be the results of mechanically responding to demand for rubber and thus the obsession to increase yield and largely through improving extraction techniques. Other aspects of agro-based research were neglected until the 1920s and even after that until just after the second world war or 1950. Periodic agitation only received token interest and research moved ahead without much planning or commitment or direction to unravel the secrets of the living factory – the rubber tree. On the technological side, much less was achieved, but the developments on the manufacturers' side calling for uniform material and great experimentation to extend natural rubber application had injected a sense of concern to improve processing methods. So the First Phase of Research was truly in its infant state.

Technical progress in consumer countries

Two other points need to draw our attention during this First Phase of Research. One, mention was made about manufacturers wanting to extend NR application. Many scientists had initiated work on eliminating the stickiness of rubber and removing its adhesive properties. But it was left to Charles Goodyear and Thomas Hancock to invent vulcanisation and revolutionise the use of rubber. And yet this was only a giant stride forward. Small quick steps taken by various other inventors also cumulatively helped the rubber industry move forward and become indispensable. Basically, these were the results of adding fillers to economise on the use of rubber, a condition necessitated when rubber price was high when first commercially exploited. With the significant development in the race to find these fillers many reactions were noted which allowed rubber to be exploited for specific use. And no less than twenty-five compounding ingredients were used by the beginning of the twentieth century and some of these either activated or retarded the vulcanisation process. The most significant development of this period was the discovery of Oenschlager who investigated the use of large amounts of carbon black, having heard of the addition of 2% – 3% of carbon black to ensure blackness of tyres. His experiments showed that carbon black greatly increased abrasion resistance of rubber, and later new types of carbon black were discovered that had more pronounced reinforcing characteristics than the use of the earlier lamp blacks. These developments in fillers, compounding ingredients, and accelerators of vulcanisation, gave a great fillip to the manufacture of better tyres more cheaply and thus the place for rubber was entrenched.

Birth of the synthetic rubber industry

The second point to note is that even as early as 1906 the German scientist, Fritz Hefmann was attempting to make synthetic rubber. This brave attempt was made when so little was known about the chemical structure of natural rubber. But patient progress had ensured by 1910, in several countries, the birth of a synthetic rubber industry. The polymer industry had come into being and isoprene, butadiene and methyl rubbers were available. Interest in wanting to push ahead with these developments waned after world war I when natural rubber re-appeared on the scene in large quantities and at moderate prices. By 1926, interest in development of synthetic rubbers was rekindled and progress was rapid in Germany, USA, UK, Switzerland, Russia and Sweden. The second world war had demonstrated the vulnerability of supply sources when S.E. Asia was almost completely annexed by the Japanese. Thus the quest for an analogous synthetic substitute to natural rubber moved at a feverish pace and by the mid 1950s this was accomplished with the invention of *cis* - 1, 4 polyisoprene. This had manifold consequence on the NR industry and even its doom was beginning to be prophesied. If this was proven to be a false prophecy then it was the result of the tremendous research achievements gained during the Second Phase of Research.

The Second Phase of Research

The second phase of natural rubber research and development and mapping of strategies extending from about 1950 to the present day may be rightly described as the period of achievement and consolidation of the industry.

Competition from synthetic rubber

Factors that pushed ahead research efforts in an organised and mission-oriented zeal were many. But the most important was the reaction to the production of the synthetic substitute *cis* - 1, 4 polyisoprene. The availability of this and other polymers had threatened seriously the once monopolistic position of natural rubber both as a material, and in some cases even challenged its superiority in performance. Once the gauntlet was thrown, the natural rubber industry had to review its research direction and emphasis was mounted to change the embedded concept that natural rubber was a back-yard agricultural commodity to one that matched the synthetic rubber claims, *viz* a scientific, modern, technically classified material. And so natural rubber met the challenge straight in the face and became distinguished as an industrial performance material no less scientific or modern and technically more acceptable than the synthetic analogue.

Technical classification of rubber

How did natural rubber achieve this ? Perhaps the first research strategy was the introduction of the Technically Classified Rubber Scheme in 1950 with the red-yellow-blue-circled bales. These designated them as slow-medium-fast curing natural rubber and though this was a popular feature, the introduction of cure rates alone in such general terms was found wanting. The industry had to meet the exacting consumer demands *vis-a-vis* synthetic rubber and had also to bear in mind improved packaging and use of containerisation. It was only in 1965 that the Standard Malaysian Rubber Scheme was launched. This replaced the visual grading system by introducing technical specifications and guaranteeing conformance to specification standards ; it moved away from the 250 lb massive bale of rubber sheets coated with talc to the 33 1/3 kg, polythene-wrapped blocks packed in 1-tonne crates for easy handling and avoidance of surface contamination ; it departed from sheet rubber to crumb or comminuted rubber, allowing easy processing and savings in energy cost at the consumers end ; it identified the sources or processes to enable ensurance of specification guarantees which were based on the presence of contaminants to attest to the purity and cleanliness of the product. So desirable were these changes that consumers' acceptance of this innovation can be seen by the rapid increase of SMR production within the last two decades (Table 3).

Table 3. *Production of SMR, 1965 – 1983*

Year	Active SMR producers	SMR production/shipment (tonnes)	SMR as % of Malaysian NR
1965	33	708	0·1
1970	115	159,403	12·6
1975	145	433,005	29·7
1980	156	561,447	36·2
1983	154	710,822	45·5

Table 4. *Production/shipment of national technically specified natural rubber (TSNR)*

Year	SMR[a]	SSR[b]	SIR[b]	TTR[b]	ISNR Ivory Coast[a]	SLR[b]	ISNR[a]	TSNR Cameroon[a]
1965	708	—	—	—	N.A.	—	—	—
1966	8 720	—	—	—	N.A.	—	—	—
1967	23 471	484[d]	—	—	N.A.	—	—	—
1968	62 569	20 452[d]	—	—	N.A.	—	—	—
1969	101 562	39 346[d]	8 400	54	N.A.	—	—	—
1970	159 403	69 264[d]	32 549	347	10 011	—	—	28[c]
1971	224 686	97 347[d]	126 215	1 636	12 026	136	—	2 796[c]
1972	282 786	87 051[d]	376 618	1 771	13 116	814	—	3 836[c]
1973	376 097	105 388[d]	361 106	1 968	13 285	815	—	6 506[c]
1974	404 906	97 694[e]	388 264	7 012	15 000	530	423	7 300[c]
1975	433 005	89 903	424 028	32 473	14 400	1 510	1 315	7·500[c]
1976	518 746	98 755	513 175	48 250	17 476	2 006	2 899	8 502[c]
1977	541 866	102 062	521 406[c]	63 654	16 840	2 024	3 256	9 760[c]
1978	555 540	86 139	568 802[c]	69 849	18 354	5 615	2 313	8 000[c]
1979	576 367	87 745	571 585[c]	94 332	18 972	14 411	1 781	7 602[c]
1980	561 447	76 285	658 254[c]	90 080	21 146	8 452	2 176	7 173[c]
1981	629 166	64 489	563 513[c]	74 470	23 100	9 445	2 090	7 720[c]
1982	649 273	47 571	579 772	79 709·4	26 742	8 099	2 161	7 900

Note : [a]Production figures
[b]Shipment/export figures
[c]Rubber Statistical Bulletin, IRSG figures
[d]SMR produced in Singapore
[e]20 854 tonnes as SMR and 76 840 tonnes as SSR
NA Not available

All figures were obtained from the national rubber institutions or governmental ministry or department except those marked with R as explained above.

The only available figures (IRSG) for Liberia were for 1972 (29 260 tonnes) and 1973 (35 285 tonnes) and for Nigeria for 1972 (16 000 tonnes). Earlier and later figures were not available.

Its popularity and world wide acceptance was so keenly evinced that similar schemes were introduced by all major natural rubber producers. The rapid progress in the production of these rubbers is shown in Table 4.

Speciality rubbers

Second, from the SMR scheme evolved the concept of speciality rubbers. Research developments, made possible by granule drying and accompanying processing innovations, brought into being tailor-made rubbers to meet specific end-use requirements. Key examples of these are : superior processing rubbers for intricate mouldings, tubes, and extrusions ; partially purified crepes for solution applications ; constant viscosity and low viscosity rubbers for easy processing ; methyl methacrylate grafted rubbers for impact resistance, novel solution properties and microcellular goods ; oil extended natural rubber masterbatch for winter tyres and belts. Meanwhile many of these speciality rubbers provided the possibility of eliminating premastication and allowed significant energy saving costs in the consumer factories.

Efficient vulcanising systems

Third, the Second Phase of Research also witnessed a redoubling of efforts in user technology for NR to compete effectively against SR and quickly respond to the scientific and technological changes taking place so rapidly. Developments of importance arising from these efforts include efficient vulcanising systems (EV) using high accelerator to sulphur ratios-yielding networks with mono, or disulphidic cross-links possessing greater resistance to reversion and ageing but inferior strength properties. The semi-EV systems which are now becoming more popular however can effect a satisfactory compromise between these features and give greater consistency and superior creep and strength.

NR in engineering applications

The outstanding elastic and strength qualities are also now exploitable in a variety of civil and mechanical engineering applications. Here the durability, resilience and improved creep behaviour of natural rubber resulting from novel methods of preparation of the raw rubber and compounding the final vulcanisates lends itself as an engineering material. Demonstrated clearly is its application in bridge bearings, earthquake mounts, springs, railway pads, cutless bearings, paddy dehusking rollers, etc.

NR modification

Fourth, to challenge the specialist role of some synthetic rubbers, work has intensively progressed to modify natural rubber and imbue it with properties comparable to the SR types like nitrile and halobutyls. Specifically, thermoplastic, epoxidised natural rubber, free flowing NR and, DPNR have been introduced.

For example, thermoplastic NR grafted co-polymers, produced either through chemical grafting or mixing with plastics, at high temperatures, has technical properties closely matching those of thermoplastic synthetic rubbers. The market for this intermediate product is most promising. More so, this innovation has created prospects for integrating its manufacture and other thermoplastic-based co-polymers into the downstream activities of the rapidly growing petroleum industry. In Malaysia, interest has been shown in using it for footwear and selected articles like battery cases where injection moulding has come to stay.

The process of producing free flowing powder masterbatches from synthetic latex has already been successfully developed by Huel in Germany. A similar process is being successfully investigated by NR technologists to produce this material using NR latex. When the process is proven it should be commercially viable for the manufacture of powdered NR and synthetic rubber blends and carbon black masterbatches for both the local and export markets. Concrete and committed action is being taken with a German associate to expedite the production of a free flowing NR-CBMB powder. Once this materialises, a significant impact is expected on the entire process of compounding and product fabrication.

Epoxidised natural rubber

Perhaps the most exciting development during this second phase of research is the production of epoxidised natural rubber. This is a process by which NR is chemically modified to enable it to be resistant to swelling in oils, and less permeable to air or gas while having vibration damping properties.

These properties emulate the characteristics of a number of special-purpose synthetic rubbers. For example, nitrile rubber is used for beltings and industrial shoe soles because of its resistance to oil, and butyl because of its air impermeability is used for tubes. Currently three grades are available for commercial testing *viz* ENR 50, ENR 25 and ENR 10. Typical values of the basic raw properties of these three grades are shown in Table 5.

Table 5. *Typical values of raw ENR properties*

Property	Grade of ENR		
	ENR 10	ENR 25	ENR 50
Epoxidation level (mole %)	10 + 1	25 + 2	50 + 2
Glass transition temperature (°C)	—60 + 1	—45 + 2	—20 + 2
Specific gravity	0·94	0·97	1·03
Mooney viscosity[a]	90	110	140

[a]ML (1 + 4) at 100°C

ENR provides a unique opportunity for NR derivatives with some speciality synthetic rubbers as indicated earlier particularly in terms of oil resistance and gas-impermeability. Also, epoxidation up to certain levels improves wet-grip characteristics without undue sacrifice to low rolling resistance and thus its incursion into the treads of passenger car tyres in place of OESBR is an exciting probability. It is envisaged that once its acceptance is worldwide, ENR 25 can hope to annually displace at least part of some 1·2 million tonnes of SR currently being used in this area. Thus producers of NR can look forward to immense benefits. For the moment it is important that production trials should help pave the way for reducing costs of production by increasing the efficiency of reaction and the use of cheaper field latex instead of latex concentrate. Tests indicate that irrespective of the source of latex the final properties are not compromised. So far, it is confidently felt that ENR will have several potential usage areas (Table 6).

Table 6. *ENR applications*

Feature	Application	Recommended ENR grade
Oil resistance	Hoses, seals, blow-out preventors, milking inflation, connectors and tubes	ENR 50 ENR 50, ENR 25
Gas permeability	Bladders, inner tubes and tyre liners	ENR 50[a]
Silica reinforcement	Where black is unacceptable and high reinforcement is required	ENR 25, ENR 50
Wet-grip/rolling resistance	Tyre treads for motor cycles, racing cars and fork lift trucks	ENR 25
Damping	Anti-vibration mountings and other engineering applications	ENR 10[a]

[a]Preferably in blends with NR

For the moment, it can be safely stated that ENR 50 can be used in blends of about 5% to confer added property improvement to motorcycle tyres without additionally increasing costs. Thus this material should command market preference.

NR in tyres

Fifth, because of the inherent properties of NR which has low heat build-up, high flex resistance, superior cord adhesion and green strength it continues to be the preferred material for the tyre industry which is now consuming as much as 70% of the natural rubber produced. The desire to economise on tyre space and volume, the predilection for low profile tyres growing, the penchant for safety and comfort in rides demanding road or surface adhesion under wet or even snow conditions, the passion to travel faster and carry heavier loads, and the preference for a longer service life, have necessitated much technological research to review the role of natural rubber in tyres and improve its percentage usage. And success in these research efforts have been more than noticed. For example the superiority of natural rubber in winter tyres has been established ; the change over from cross-ply to radial ply is also perceptibly being undertaken to ensure greater comfort in rides and longer service life apart from ensuring increased safety. In these applications, particularly in heavy duty tyres, the displacement of natural rubber cannot be envisaged. Changing transportation systems like greater use of the mono-rail systems either subterranean or overhead in the air may even bring back the use of pneumatic tyres to reduce noise vibration and improve travelling comfort. Here the use of rubber wheels has also shown attraction. Allusion was also made to the exciting performance of ENR and indeed one can envisage a greater proportion of natural rubber usage even in ordinary passenger car tyres in the initial stages although, in some cases, the total usage of NR will be balanced because of the extended life of radials.

Thus, during the Second Phase of Research, the neglected area of technological and end-use research moved ahead in leaps and bounds. There are many more exciting areas in which work has started but where the hoped-for results will have to be waited for patiently. The point that needs stressing here is that natural rubber technologists, chemists, physicists and engineers are matching and in some cases have even shown a greater research enterprise than their counterparts in the synthetic rubber industry.

Research advances at the agro-biological level

At the agro-biological level, there have been distinct gains arising from the co-ordination of research and more importantly in selecting or setting-out priority objectives. The achievements have been of two kinds : one making outstanding contributions to work already initiated in the First Phase of Research, and second moving out in new directions in answer to the technological challenges and changes presenting themselves with each new day.

The more outstanding of these developments deserve to be mentioned however briefly and their consequences asserted.

Ensuring greater yield and earlier maturity

As in the first phase, the improvement of yield has always been a top priority. And what was produced in 1920 has been surpassed almost ten times at this point of time. But the breeding and selection programmes that gave rise to this phenomenal increase, did not achieve it at the risk of secondary characteristics. Indeed, the many pronged studies were aimed at evolving the ideal tree.

An important attribute of the new clones that have indicated yield as much as 5000 kg/ha/year, the RRIM 900 series clones, is the fact that they are precocious yielders. This means that in the first year of tapping these newer clones can yield as much as 1000 kg/ha/year compared to the 600 kg to 700 kg/ha/year obtained from the popular RRIM 600 clone. In terms of economic benefits, the returns are obvious.

Reduction of breeding cycle

Because rubber is a perennial crop, breeding and selection is not only time consuming but an expensive process. Early techniques demanded an investigation period of at least 30 years. This traditional breeding cycle period has been presently reduced to 20 years, and efforts are continuing to shorten it even further by clonal evaluation methods at the nursery stage. If nursery yield exceeding 0·35 g per tree per cm from six tappings is the selection criterion then more than 80% of the high yielders would have been selected. But the important thing to note is that only 50% of the clones need to be tested further.

Therefore, by setting an appropriate nursery yield criterion, it is possible to reduce substantially the effort of testing without significant sacrifice to selection efficiency. This represents a distinct improvement in the efficiency of breeding and selection techniques. The threshold of maximum yield is yet to be neared as the figure of 9000 kg/ha/year is still half-way ahead. But the progress so far attained gives confidence that the limits of maximum yield capacity is not beyond the reach of sustained research.

Stimulation and its effects

Already, the Second Phase of Research has introduced the element of successful stimulation. Stimulation of latex flow is principally an exogenous process to increase the yield above that normally obtained by tapping of a tree. The methods that have been employed cover a wide spectrum and have progressed from simple physical techniques in the early years to more refined and effective chemical methods. Stimulation of latex flow is now an integral part of most exploitation methods. Basically what happens is the plugging of the latex vessels is delayed allowing a prolonged flow.

A wide range of substituted phenoxyacetic acids and substituted benzoic acids were screened for stimulant activity during the period 1956 to 1958. Results from screening some of these compounds revealed that yield response increased (a) with increase in chlorine atoms substituted in the benzene ring and (b) with decrease in the atomic weight of the substituted halogen. But because of cost factors the early stimulants 2, 4 - D and 2, 4, 5 - T were used. However later studies, particularly in the sixties, revealed that the use of a gas could be more effective, and thus the positive stimulant action of acetylene and ethylene was confirmed. The large-scale use of stimulants also meant that the method of application had to be investigated to prevent toxic effects, conserve bark consumption, reduce tapping skill and frequency. Thus, stimulation has brought in its train new concepts in regard to tapping systems. It will be enough for the moment to mention that stimulation in combination with appropriate tapping systems can give extra yields. In some clones this can range from fifty to eighty percent. This is an extraordinary achievement with three clear gains. First, when needed extra supply of yield from available trees can be extracted investing the crop with an element of elasticity in supply while adopting conventional tapping frequency and intensity. Second, with reduced tapping intensity or frequency, labour inputs can be drastically reduced, contributing to lowering of production costs and obviating labour shortage problems in some producing countries. Further, even the requirement of skill demanded in conventional tapping can be overcome through puncture tapping systems. Equally important, bonuses from this new exploitation systems also means more effective extraction of latex from trees in monsoon affected areas, where conventional tapping is discouraged during the rainy seasons ; a longer economic life for the tree, and a reduction of the immaturity period since tapping can be commenced at relatively small girths.

Reduction of immaturity period

In discussing the reduction of immaturity period, distinct gains have been made to make rubber a viable economic investment compared to oil palm. The long gestation period of about seven years has meant no economic returns during this period. Under the situation, it is the smallholder who is put under economic strains. Relative to other crops, like oil palm and cocoa, this long wait acts as a depressant. Interest in cultivating these other crops is not only activated but fulfilled at the expense of rubber cultivation. Research has therefore investigated various techniques to reduce this period of field immaturity basically through improved agronomic practices which can now bring the tree into tapping within four years. In combination with cash cropping and mixed farming during the immature period, rubber growing can still be a profitable enterprise.

Discriminatory fertiliser usage

Parallel achievements have also been significant in other agro-management areas. Here I wish to draw your attention to some major gains. One of these is the move towards systematically classifying soil types in order to study the influence of their physical structure and nutrient status, and their interactions on the successful growth of *Hevea*. As a result, it is now possible to advocate the judicious use of fertilisers and tailor-made fertiliser recommendations are available to derive the best from planting materials in relation to specific soil types. Manuring under stimulation too has now become an exact science. Correct use of fertilisers during the immaturity phase can help reduce the unproductive phase of rubber by at least one year, contribute to overall yield improvement and consequently reduce the unit cost of production. Recently, it has also been established that appropriate application of fertilisers during the early years of rubber growing can, during the mature phase, be withheld for a defined time-period without negatively affecting yield. This is a useful safety-valve aid in times either of high fertiliser prices or low rubber returns when the use of fertilisers can be withheld for a period and expenditure over one item be curtailed. Research has fairly advanced in the encapsulation of fertiliser with a thin coating of latex to produce slow release fertilisers and prevent losses through leaching.

Effluent control

In these days of the pollution syndrome stirring the conscience of the world, the rubber industry has successfully researched into effluent control to reduce pollution from rubber factories. It has been established that since the resulting effluent from the various processing methods is very amenable to biological break-down (high BOD/COD ratio) the treatment processes employed are biological. Thus far, two treatment systems are recommended, depending upon the location of the factory. One is the anaerobic/facultative ponding system and the other is the oxidation ditch. Research is continuing to improve both these systems and alternatives are also being looked into to reduce the pollution problem by 100% from the present 85% success. The waste products are being looked into as energy sources, fertilisers and feedstock for fish and animals.

Crop protection

Control of diseases and prevention of pest attacks have been improved to reduce costs of treatment. In the process expensive machines, have been redesigned or adapted to simplify the equipment and reduce capital investment in these machines. Application of fungicides for control of leaf diseases through these new approaches have led to increased productivity and consequently enhanced returns (Table 7).

Table 7. *Approximate gain in controlling diseases of rubber trees*

Disease	Method of application	Chemical	Cost of treatment ha/yr (M$)	Increase in yield/ha/yr (kg)	Increase in income per ha/yr (M$)[b]	Production cost[c]	Nett gain per ha/yr (M$)
Oidium SLF	Dusting	Sulphur	67	118 to 173	302 to 443	190 to 279	45 to 97
	Fogging[a]	Tridermorph	152	93 to 173	238 to 443	150 to 279	–64 to 12
Colletotrichum SLF	Fogging[a]	Captafol	99	188	481	303	79
Secondary leaf fall (*Oidium* and *Colletotrichum*)	Helicopter spraying	Phytar 560, MSMA or merphos	34	221 to 622	566 to 1592	356 to 1001	176 to 557
Phytophthora leaf fall	Spraying	Copper oxychloride	174	116	279	187	–64
	Fogging	Captafol	75	121	310	195	40
		Copper oxychloride	26	179	458	288	144
Black stripe	Brushing or spraying	Captafol	163	310	797	499	135
		Metalaxyl	136	310	797	499	162

Note : [a]Fogging includes the depreciation of the machines

[b]Calculated on the basis of the current rubber price of $ 2·56/kg

[c]Calculated on the production cost of $ 1·61/kg (mean of 1978 — 1982)

Rubber wood exploitation

Hardly 10 years ago, rubber wood was almost entirely used for fuel, mostly for smoking rubber and the rest for domestic firewood. Today, research has shown that it is an attractive light hardwood and can be used for making furniture, panelling, parquet, chipboard, packing crates, and window louvres, etc. This wood is particularly well received in the USA and Australia. As rubberwood is quite susceptible to attack by borers and blue-stain fungi, the treatment of the felled tree and sawn wood has to be effected quickly and thoroughly. Research on improving the treatment systems, drying of the wood and expanding its usage is continuing under a joint committee in Malaysia between the FRI and RRIM. In 1983, Malaysia exported about 19 million dollars worth of rubberwood.

The ability to exploit the use of rubberwood has three distinct advantages. First, because of its increased value, replanting can be hastened in areas where planters, particularly smallholders are reluctant to replace the old material with the new high-yielding varieties. The cash to be obtained from the sale of the wood acts as an incentive to replant. Second, wood which was used largely as fuel and was regarded as economically valueless can be utilised to maximum advantage and deforestation through excessive exploitation of regular timber can be conspicuously reduced. Third, the question of breeding trees to yield much more latex for a shorter period and then utilising the wood could transform the objectives of rubber cultivation and can endow the tree with two assets — latex and timber.

Research strides ahead

From an almost random survey of the impact of research during the second phase or as some may prefer to call it present times, it is indisputably seen that during this phase, research and development proceeded on a priority basis well hinged to clearly declared objectives. Visibly too, technological research moved rapidly ahead in answer to the birth of the SR industry and in tempo with its new influence as a polymer. In the arena of agro-bio research there was no trial and error devices to ensure progress, but there was a methodical and careful investigation of the multifarious factors that condition the growth of rubber, influence its yield, and enhance its value.

Organisational co-operation

But this Second Phase of Research was not purely a field day for research progress. Three distinct developments took place and these need to be briefly announced and introduced here as they have an important bearing on the future development of the rubber industry.

This period may be said to be the true era of regional and international co-operation. I refer here to the birth of the Association of Natural Rubber Producing Countries, and the International Natural Rubber Organisation. There has been more intensive co-ordination and co-operative ventures undertaken between rubber research institutes on their own and importantly under the aegis of the International Rubber Research and Development Board, which was somewhat inert in the first phase, largely because of its limited membership and partially because it was unsure where it was to go.

Birth of the Association of Natural Rubber Producing Countries (ANRPC)

We had seen how as early as 1922, go-it-alone approaches to alleviate problems affecting rubber producing countries could not be solved. The International Rubber Agreement of 1934, though an improvement in exhibiting co-operation was largely a convenient arrangement. The ANRPC was necessitated because of falling rubber prices but was really prompted by the forceful reason that NR-producing countries had to get together and fend for themselves earnestly. In October 1970, the ANRPC was established with six member nations, *viz* Indonesia, Malaysia, Singapore, Sri Lanka, Thailand and the Republic of Vietnam. They together produced 85% of the world's rubber in 1975. Today it has a total of seven countries and they produce 86% of the world's NR amounting to 3·4 million tonnes in 1983. The objectives of this association are straight-forward. These are :—

(a) to bring about co-ordination in the production and marketing of NR,

(b) to promote technical co-operation amongst members, and

(c) to bring about fair and stable prices of NR on the world market.

A strong body such as this with the backing of the governments of the producing countries can be an effective representation in world forums on rubber matters, as it can speak with a single voice on behalf of producing countries. Further, among themselves various co-operative actions can be taken to develop the rubber industry. Two recent examples, one of political or economic significance was the agreement to curtail production of NR on an agreed formula to encourage the price to reach a fair level. A second example of its wise collective action was the Agreement that was signed amongst them to prevent the spread of the dreaded and most destructive disease South American leaf blight and what phytosanitary measures should be taken. The ANRPC too organises regular seminars to evaluate the progress of research in member countries and facilitates the exchange of information. Most importantly, it attempts to develop strategies for the improvement of the industry and to realise this end, several co-operative steps have been taken. This is therefore a most important development and has far reaching consequences.

Role of the International Natural Rubber Organisation (INRO)

On the International level, both consumer and producer countries met to sort out the vexatious question of rubber price fluctuations. And this getting together again is a lesson of practicality for mutual security. Unlike the OPEC stance of intimidation through unilateral decision, the INRO concluded in 1979 and ratified in 1980, demonstrates the desirability of producers and consumers coming together to establish a floor and ceiling price for NR. It is in this cordial atmosphere that any mutually beneficial and lasting agreement can be negotiated and accepted.

Naturally, there will be cynics who question the wisdom of this co-operative move remarking that the price levels have never been fair to producers. But they only know the price of everything but not the value of anything. The fact remains that the mechanism of ensuring price stability has been tested and its value as a safety net or insurance particularly for smallholders benefit has been proven. No one can deny that there are avenues to reappraise the price levels and here consuming countries should be more realistic and not kill the goose that lays the golden egg through negative attitudes.

International Rubber Research and Development Board (IRRDB)

The IRRDB became very active in co-ordinating the exchange of views and information among member countries. This was not done as in its initial years through discussions in Board Rooms, but through regular seminars and discussion meetings among the scientists on a planned basis on specific topics for the benefit of all NR producing countries. Often these meetings are held in the premises of the Rubber Research Institutes or they help host them. Perhaps its most ambitious co-operative programme was the Amazon Mission of 1981 when a group of scientists from the Rubber Research Institutes of Malaysia, Thailand, Indonesia, China, Ivory Coast and Nigeria, with the kind consent and co-operation of the Brazilian Government, went to collect seeds, budwood and seedlings. This was successfully accomplished as the expedition netted 64,000 seeds and 152 m of budwood over a period of one and a half months of collection. The potential development from widening the genetic base is immense and quite obvious that it needs little emphasis at this point.

We see clearly that during the Second Phase there is growing regional and international co-operation, a pooling of resources, a sharing of expertise and it is well to turn this understanding to good account for the future benefit of the industry.

Energy costs and its impact on NR

Another major development during this Second Phase was the effect of the energy crisis. This took place in 1974 with oil prices escalating and severely jolting the industrial world. At that point of time, it meant that NR producing countries could not be blackmailed with the threat of cheaply derived SR, although the brakes being applied on the wheel of industrial progress meant reduction of total polymer usage which also had its side-effects on NR usage. The message of this swift and severe unilateral upward revision of oil prices forced a reassessment of the future of non-renewable resources *versus* rubber, a replenishable material. It was slowly being realised that over the long-term it would become progressively expensive to produce SR and thus it would be better to come to reasonable terms with NR producers. This may well have been a key reason for the INRO to have been negotiated in 1979.

The pragmatic reaction to the sharp rise in oil prices was the deliberate and conscious move to save as much energy sources and use it as sparingly as possible. Alternative sources were also investigated and new sources harnessed for man's benefit. This tightening of usage combined with alternative sources of energy, and unstable political conditions in some oil producing countries seem to suggest an ' oil glut ' situation at present. However there is no escape from the view that petroleum resources are depleting and certainly, at least, that it is not cheap. The cost increase for a barrel of oil between 1970 and 1980 is given in Fig. 1.

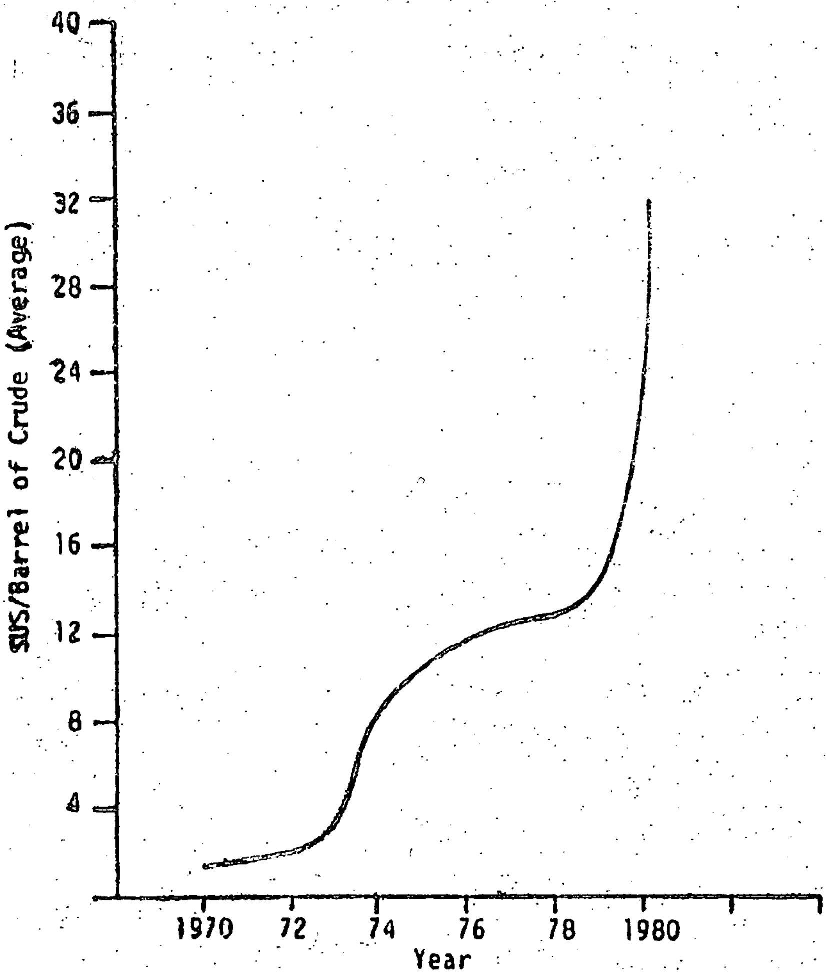


Fig. 1. Average price (US$) per barrel of crude oil, 1970 to 1980

Despite the 'glut concept', it has been driven home that expensive SR is not the real answer to meet the world polymer requirements. Afraid of inadequate supply of NR and doubtful of supply sources. USA, the largest consumer, made moves to increase it's NR stockpile to 850,000 tonnes, there was also serious operations to reactivate research on alternatives to natural rubber, *viz* guayule. Despite the difficult petroleum situation, USSR is also known to have produced large volumes of *cis* 1, 4 - polyisoprene. All these go to show that large consumers are unsure about the future of NR supplies. The only way to assuage this fear is for producers to re-affirm their ability to produce sufficient supplies of consistent material at reasonable prices and not lose out by default.

What then is held in store for NR in the future and how should research and organisation gear itself for the take-off.

Let me start by continuing with the energy situation.

Synthetic rubber, a complement to natural rubber

The birth of the polymer industry and the revolutionary technological changes has meant and will mean greater use of polymers. Despite the dangers inherent in forecasts, one can boldly state that the demand forecasts of NR has been set at 6·8 to 7·05 million tonnes for the year 2000. This is almost double that consumed in 1983. It was in preparation for such large increases that the industry was motivated to produce or perish and the dynamic production policy was introduced. But the onslaught of extended recessions, sharp inflations and slides in oil prices over the last 3 years were not clearly seen and its impact not accurately analysed. Rubber prices under these situations naturally received several sharp knocks. The point is not to despair over such miscalculations but to use such conditions to reappraise the situation. And here two suggestions are offered.

Taking the petroleum industry, one should recognise that the present relatively low prices are only a temporary phenomenon. Thus at future higher prices it will not be sagacious to use petroleum for fuel as a source for producing materials which will substitute natural materials which are renewable assets and importantly contribute to a clean environment. Rather it should be used for making higher value products like fine chemicals and speciality materials for which there is no equal. Thus the production of general purpose SR should be discouraged, and NR be allowed to gain its rightful place and this makes a common sense assessment. Since the source for NR manufacture is basically the free sunlight and only supplemented by fertilisers, machinery and labour, it is bound to be cheaper in the long run. A comparison of the energy content of synthetic rubbers with NR will show how much savings in energy can be made if all SR is replaced by NR. The calculated figure is 500,000 barrels of oil per day. But this is not the request. The idea is to allow NR to compete freely and the SR industry should confine itself to speciality rubbers as yet unmatched by NR modification. Assuming this principle is acceptable and agreeing to an even more pragmatic usage ratio, NR should have a share of at least 40% of the world market with 50% for SR and 10% left for open competition. On this basis a minimum of 7·2 million tonnes of NR should be readily available by the year 2000.

While it may be a great risk to limitlessly produce NR and therefore depress prices because of the forces of a demand-supply equation, the NR industry must move towards controlled production and should at no time encourage a surplus situation to damp down prices. And yet the strategy should be such that there should be an assurance of supply.

Future of exploitation and collection systems

Here a second aspect of research needs to be investigated intensively. Alternative stimulants, even better exploitation systems with less stimulant concentrations will not only ensure the elasticity of supply, but will be able to provide means to overcome the skilled aspect of conventional tapping, the time consuming aspect of tapping and collection systems and overcome labour shortage problems and increased labour costs. For the immediate future it means further refinements to the recently started experiments on automated or mechanised tapping which indicates that work productivity can be doubled. The time taken for a tapper to walk between the trees is also a significant factor affecting work productivity. This must be reduced. So future research must look into not only planting density but also the width of interrows. This will mean also looking into collection systems. Merely looking into the advantages of a clay, plastic or glass collection cup is not sufficient. The sights should be fixed at less regular tapping, say weekly, and collection of the latex in plastic bags which could be collected monthly. All the necessary chemicals that need to prevent coagulation of the latex in the bags have to be allowed to drip into the bag by controlled mechanical devices. These are areas which can be productively investigated within the shortest possible time. For the distant future, we could visualise or fictionalise by dreaming of micro-chip aided gadgets affixed to each tree which will allow for robotic puncturing of the tree at desired places and time intervals, regulate the application of stimulants to extend flow time and permit the approved amounts of chemicals to prevent coagulation of latex. This would flow through tubes down the tree to meet at junctions of a continuous pipe or channel linking all trees in a row and ultimately leading to a point of collection. We are now envisaging a kind of system that is used to collect the maple syrup in Canada, and in fact such futuristic systems are already being investigated. It must be impressed upon the minds of researchers that the dream of today will become the reality of tomorrow. With committed efforts and sufficient research fund backing, nothing should seem impossible for tomorrow.

Bio-technology and future impact

Indeed, the difficulty of raising *Hevea* progenies through tissue culture expressed ominously only a decade ago is being slowly but surely realised. China who have had a shorter association with *Hevea* have successfully advanced in this area and have produced plantlets and trees. The efforts in Malaysia can now produce plantlets from somatic callus of RRIM 600. In this biotechnology effort, the narrow aim of merely producing progenies of exact likeness and characteristic of mother plants, or for uniform planting materials and reducing the breeding time needs to be broadened. The developments in tissue culture should enable us to develop protoplast fusion techniques which will enable genetic manipulation. Biomodification of rubber too needs to be looked into. More efforts should also be directed to induce mutation in *Hevea* to produce new forms of variability. In this regard ionising radiation technique alone may not be sufficient. We may have to look into the use of laser beams to destroy or seal off undesirable characteristics and allow the plant to express its growth as we determine. Three aims should demand priority. One the creation of dwarf trees, two the inducement of disease resistance and three the encouragement of timber formation. The overall aim should be to breed trees that will not only yield immensely during their productive years, but also give these higher yields earlier in its life time. We can thus effectively shorten the present economic life span of 30 years to perhaps 15 years, having capitalised on it for 12 or even 13 years. This is not an unreasonable expectation for using the new tapping systems like puncture tapping, micro-X and so on in combination with stimulants and an appropriate fertiliser programme we could start tapping the tree when it is 2 or 3 years old, even though the girth may be relatively small. Once the economic life is reduced to 15 years, we can then chop down the tree and use it as timber. These are the areas for future development and they are all within reach in our life time.

Growing rubber under new conditions

The growing of rubber has always required certain climatic conditions. Could not future research refute this principle ? The Chinese have shown that it can now be grown in sub-tropical monsoonal areas. They have researched for sometime now and have attempted to explain the effects of cold waves on rubber trees. In the process they are breeding cold-enduring clones with high yielding potential. GT 1 is said to withstand a temperature of 0°C for a short while, while China-bred clones 93 to 114 can stand a temperature of —1°C. In India, drought resistant clones are being sought.

The lessons from these exciting examples are that almost nothing is impossible in research, provided there is patience and commitment. As the competition with more lucrative crops become more serious, rubber must move into areas facing soil and climatic constraints. There are large tracts of land in all producing countries which cannot support competing crops. Research must establish a basis for using these areas for rubber with positive economic gains.

Naturally technical specified rubber

In the efforts to produce the ideal tree, biologically, grafting techniques were used. Today we have trees with good rooting systems, high yielding trunks and desired canopies. The immediate gains are that we have tailor-made combinations for different environments to extract the maximum from a combination of clones. In the process, it was noticed that there was interaction between the grafted clones for canopy and the trunk clones for yield and this affected the Mooney viscosity of rubber. Here then is clear proof, that biomodifications of Mooney viscosities will be possible. Recombinant DNA techniques would be relevant. For the present it is enough to be reassured that combinations of clones can affect the technological characteristics of rubber (Table 8).

Table 8. *Effect of trunk crown combination on Mooney viscosity of rubber*

Crown	Trunk		Control
	PB 86	RRIM 501	
FX 516	56	38	4
FX 25	82	71	8
Control	77	40	—

The future for research on the technological fields is immense. We have, however, to confine ourselves only to considering a few.

The desire for automation, continuous processing and fabrication procedures, reduction of energy inputs, means of evolving better vulcanisation systems, compound mixing techniques and finer working materials are all becoming manifest. In anticipation of these changes, the natural rubber industry must evolve the requisite technologies and innovations. Questions that must tax the researchers include :

(a) What can be done in vulcanisation – use of bound anti-oxidants, built-in crosslinking groups, self reinforcing structures ?

(b) Easier mixing with powdered and liquid rubbers. What directions should these take ? How can the technological characteristics be controlled in the process ?

(c) Modified rubbers – what can be hoped for from NR ? Can biotechnology help using recombinant DNA and or bacterial systems ? Epoxidation, hydrogenation etc can be techno-economic targets.

(d) How will the use of micro-wave, micro-chips and computers fit in with NR processing, fabrication and manufacture ?

These and others should receive the concentrated attention of researchers in the future. The bread and butter operations required for the immediate period ahead have already been identified and are at different stages of initiation. These include :

Review of SMR scheme

The SMR scheme which is nearly 20 years old is to be totally reviewed next month. In the existing scheme the aim was to eliminate contaminants and thus specifications were tightly built around this concept. Now there is need to emphasise on quality and consistency and to move away from defining source materials and processes and emphasise on the performance of the material. There is need to advocate this conceptual change and the dichotomy between sheet and crumb rubbers need to be resolved. Specifications should be based on the three Ps – Purity, Processability and Performance. Thus attempts should be made to introduce specifications which will include breakdown index, cure rate and vulcanisate properties. In evolving the scheme to meet the advancement of technology and exacting demands of consumers, it is vitally desirable that consumers and producers freely exchange their views and arrive at the best possible decisions. Here again, the continuation of dialogue to reach excellence through cordial cooperation must be ensured.

Integration of production and manufacture

In the past, and to a large extent even at the present, the producing countries were happy just to export the raw material. That approach and attitude must be changed. The future for NR producing countries must be found in progressively entering into the manufacturing sector.

Thus a more planned and conscious direction should be given to integration of raw rubber production with rubber products manufacturing. The wisdom of this attitude is self-evident. The raw material is necessarily cheaper at the source. The possibilities of making the new, speciality rubbers like powdered, thermoplastic NR are more economically viable when they are close to the tree. Indigenous technical and scientific skills are now available and there is confidence in self-reliance and capability. By establishing manufacturing processes close to the rubber growing areas, the dangerously free flow of people from the rural to the urban centres causing social and cultural upheavals can be discouraged. The advantages of various infrastructures necessary for modern factories can ensure spillover benefits to the rural areas. Lastly, the producing countries which are still basically agricultural can slowly transform themselves to a semi-industrial state.

The practicality of such a move has been demonstrated in Malaysia. Here, there have not only been indigenous efforts to move into the manufacturing sector, but with incentives offered by the Government several joint-ventures with overseas partners have been established successfully. Thus the call by the Government for an NR industrialisation programme. In this direction, there is need to consider if there is room for an indigenous plant to manufacture synthetic rubber, particularly SBR. For blends of NR and SR also have a potential market, and more immediately it could help accelerate the incursion into various manufacturing sectors as in Japan, South Korea, Taiwan and Brazil. Their impact as rubber product manufacturing countries has grown phenominally, especially in the manufacture of tyres which is achieved through consuming a greater proportion of SR. This idea is also consonant with the future aim of producing powdered rubber masterbatches, from natural latex which can be readily blended with locally manufactured SBR.

Effective marketing

Some 15 000 types of rubber goods are manufactured in Malaysia and 200 of them can be classified as major divided into fourteen groups, namely tyres and wheels ; inner tubes, valves and tyre curing bags ; footwear and related components ; latex dipped and extruded products ; latex foam products, household products like gloves, water hoses ; engineering products ; automotive rubber parts ; adhesives, sealants and tapes ; compounds and masterbatches ; commercial pipes, hoses and tubes ; sports goods ; rollers and miscellaneous products like catheters, rubber bands, etc.

Their product quality is second to none and most of them are produced for the export market. Yet, manufacture can be extended and expanded if only the marketing strategy and efficiency can be improved. Even with some of the new speciality rubbers there is unnecessary delay in the take-off. Thus for the future, we must think of sophisticated marketing strategies, with sustained follow-up action, guaranteed by efficient technical backup services. Since a not insignificant number of these manufacturing agencies are small, they are immediately interested in developing import-substituting activities. The larger ones are generally joint-ventures and therefore because of their lead and certain market outlets they are meant to be export oriented. There is no reason why the indigenous product manufacturers should not look abroad for market expansion. Research is therefore necessary to organise market surveys to promote products on an aggressive basis. The need is for organising an effective overseas marketing and sales service, regular participation in international trade exhibitions, accompanied by wide and effective advertisement. A coming together of these manufacturers under a strong centralised body to co-ordinate such activities will not be wasted time or effort.

Regional and international co-operation

If national co-operation is advocated, then this must be urged at the regional and international levels. At the regional level the ANRPC can help crystallise the strategies for the natural rubber industry and can implement them with force and urgency in the respective member countries. Recent cooperative action has been mentioned ; but a concerted action to improve the back-bone of the industry, the smallholder sector and to ensure they can quickly absorb the available technologies and improve their productivity is urgently desired. The socio-economic importance of rubber has been stressed and it is important to remember that over 75% of total world production is by smallholders and subsistence farmers, who typically own less than 5 ha. Thus the livelihood of an enormous number of people depend directly on this important crop. Any neglect which undermines this great industry could only lead to unimaginable and undesirable consequences.

At the international level, I would suggest that under the auspices of the IRRDB, particular projects which are of common interest, or too much of a financial burden, or even too much on the demands of available expertise in a single research institute to proceed with, should be jointly pursued. At the larger institutional level, an international rubber research programme can be evolved by the IRRDB. At the micro-level, on a specialist topic, the IRRDB could introduce a Research Fellowship for an individual to be selected on the basis of excellence for a period of 1 to 2 years to work unfettered on the approved or contested project. This will remove the isolation of scientists in developing countries by giving them opportunities for working with their colleagues in neighbouring regions and even in developed countries. For the NR producing countries this could provide the stimulus necessary to engage in fundamental work, rather than be too rivetted to the routine demand of adaptive or mission oriented research. In contributing to these research travels and investigations, I would dare say that the proposed IRRDB Fellowships could provide a new stimulus to the research institutes and the researchers. The risk-opportunities must be there for the bold and brilliant to investigate and experiment. And this means they needs the time, the funds and the backing. The awarding of such research fellowships, I forewarn, must be based on scientific excellence, otherwise bureaucratic practices and positional importance might diffuse aims and alter targetted objectives.

The IRRDB should also use its good offices to seek for substantial funds from international bodies to undertake named research projects. Research institutes are now in the grips of budget constraints, and with a prolificity of research staff, proportionately less money becomes available for research activities. Under such situations, the bread and butter jobs must proceed unhindered. Any new item of research which suggests possible returns but has little evidence to indicate this is likely, in fact is most certainly to be rejected. The frustration of the researcher only grows and he becomes *fait accompli* to mechanically move on with his given assignment. To prevent such slides into the intellectual morass, individuals could with the support of the Institutes, present a case to the IRRDB for its consideration for funding. Indeed, even Research Institutes could suffer this same sense of frustration and under such a scheme they too can approach the IRRDB to obtain special funding for special projects from international organisation.

The IRRDB has initiated some moves in this direction. Two projects funded by the Federal Republic of Germany through UNIDO are at present contracted out to IRRDB institutes. One on natural rubber composites is undertaken by MRPRA and the other on liquid natural rubber by IRCA. The development of an international rubber research and development programme and the institution of IRRDB research fellowships perhaps represent the most prudent and cost effective method of utilising scarce funds from international sources. Money is not utilised for "brick and mortar" but for the approved research activity using the available skills in existing institutions.

International Journal of Natural Rubber Research

In thinking of the future, it has been thought necessary to launch an International Journal of Natural Rubber Research. This would discourage any residual fissiparous tendencies among existing rubber research institutes and would positively encourage a vehicle that will publish the very best of research on all aspects of rubber. No better way of achieving this is seen than by expanding the scope of the almost 60 year old and world-wide known Journal of the Rubber Research Institute of Malaysia. If the Rubber Research Institute of Malaysia can forego the instinctive desire to build and propagate its excellence for the common good of the natural rubber industry, then I expect all rubber research institutes to freely contribute to this new Journal of Natural Rubber Research which will be launched in 1986. For the moment it is enough to note that it will have a Board of Editors numbering at least twenty scholars and scientists representing different disciplines and who will be from all over the world.

As the Journal will be published by the Rubber Research Institute of Malaysia, on behalf of the Malaysian Rubber Research & Development Board, the Editorial Committee which will be the working committee — will consist of members from the MRRDB, MRPRA and RRIM.

Perhaps, I have prematurely announced this intention. But it is with a purpose, as I wish to see the reaction of other rubber research institutes to this idea of having a journal that will clearly and effectively represent rubber research progress in all parts of the world. This exercise is also to underline my previous thoughts on the continuing need to cooperate and pool our resources and expertise and establish a united front for the rubber industry.

THE PLANTATION SECTOR CHANGED CHALLENGES AND PERSPECTIVES

By

U. PETHIYAGODA
(FAO Consultant)

In choosing an appropriate subject for this occasion, I have been influenced by the considerable attention paid lately in the popular international agricultural press to issues relating to development – particularly in Third World countries.

An audience assembled to mark 75 years of research attention by a renowned Institution to a crop of much strategic importance as rubber, seems a singularly suitable one with whom I may share some of the concerns that have been expressed. Changes of emphasis that seem to be dictated by the ongoing debate are of undoubted and deep relevance to our country and its plantation sector.

I cannot hope to do justice to the enormous volume of relevant material that has recently been published – for, apart from the sheer bulk, much is controversial and some highly specialised. None can assimilate it all. The most I could endeavour is to select some of the more salient matters of the most direct applicability to our own situation and to hope that the resulting ' collage ' will have some semblance of design and form.

The history of our plantation enterprises and the current statistics relating to extents, production and earnings are so widely known and often quoted that I will reduce to a minimum, my need to refer to them in detail except where necessary to sustain a particular point.

That our country possesses an ample agricultural capability, a deep and long-standing tradition of agrarian life and a population of competent farmers, officials and scientists is doubtless true. That recent decades have seen a surge in activity, production and plans and some results, is equally evident. The question is whether adequate use has been made of our resources to match and meet real needs, whether objectives have been recognised with clarity and whether potential pitfalls have been seen. In short, could and should we be doing better in our agriculture.

Anxious to bring myself up-to-date with the local scene, I have rather carefully perused the daily press during the past few months – and am impressed that hardly a day passes without the appearance of some relevant – and often substantial item relating to agriculture. While this is encouraging in that multi-pronged action is indicated – at least on paper, it is also frustrating as it leads one to feel somewhat short-charged on results !

Agriculture primarily means food. The principal obligation of farming in a country is to meet the needs of its own people. However pressing the need for foreign trade in agricultural produce – and it is not possible to conceive of it ever being more pressing than to provide ones own people with the means for a decent and dignified life – this perspective should not be allowed to get lost.

During the past two decades or so, Africa South of the Sahara has remained the World's principal food problem area. In no small measure due to its forgetting its own peoples. There are several points of difference between our condition and theirs which may seem to reduce the validity of direct comparison. However, two features are worrying – one is the great rapidity with which the deterioration has occurred and the other, the regularity with which numerous studies on the situation have laid blame on the excessive concentration on industrial cash crops for export with resultant neglect of the sector concerned with food production for local consumption.

Sri Lanka is poised for historic developments in the agricultural field. The Mahaweli Scheme, prospective self-sufficiency in rice, diversification of the agricultural base, the definition of a National Science Policy and the creation of an Agricultural Research Council are some important impending events. The plantation sector and its supporting Institutions (not least among them the Research Institutes) cannot afford to be excluded in the resulting process of integration and future progress.

Many countries which today rank among the poorest of the poor and whose peoples face starvation and stark famine – were not so very long ago, regions of dazzling abundance. The reasons for the reversal are many and varied and include climatic changes, soil impoverishment, uncontrolled population growth, technological inadequacies, political instability, urbanization, policy errors and several others – the particular mix and relative importance varying from situation to situation.

In a provocative book titled " Food for beginners " by Susan George and Nigel Page is quoted the following passage. It is from a note written by a French colonial officer from Upper Volta to his Government and concerns the drought of 1932 :—

" One can only wonder how it happens that populations who always had on hand three harvests in reserve, and to whom it was unacceptable to eat grain that had spent less than three years in the granary have suddenly become improvident. They managed to get through the terrible drought years of 1912 – 1914 without hardship. . . . Now these people, once accustomed to abundance, are living from hand to mouth. I feel morally bound ", the writer continues, " to point out that the policy giving priority to industrial cash crops has coincided with an increase of food scarcity ".

The book from which this quotation comes and which promises to become as widely discussed and controversial as Rachel Carson's " Silent Spring " – unless it gets strangled early — lays blame on the colonial powers and their successors multinational agribusiness, development agencies and even the " green revolution " as having brought about this effect.

A further telling point is that developing countries – which are the most dependant upon trade in primary agricultural commodities – have no control over prices. When prices drop, the countries try to increase production in order to maintain earnings. This means that more land, imported fertilizer and labour is devoted to commodities and less to food.

And whether we like to admit it or not, revenues so generated by Third World countries are used to buy consumer goods to appease urban elites – thus in effect taking value from the countryside and returning it to the cities.

I would add that apart from spells of euphoria brought on by periodic and temporary peak prices – as is happening just now for tea – commodity prices have shown only miserly improvement compared to the steady escalation of prices of all inputs. Unable to influence either end – the industry under pressure is obliged to cut costs. The only ways in which it can do this is by underpaying labour (sometimes referred to as improving output (!) or by cutting on capital investment.

David Hopper, Vice-President for South Asia of the World Bank states "For 80 per cent of the World's population, development means agricultural development. World prosperity is linked to urban prosperity. It is essential to get the idea across to Governments that prosperous towns need prosperous rural areas. And, given a chance to make a profit, the farmers will feed the townspeople – and stop much of the drift to the towns. Self sufficiency in food" he says "Is the key to survival, especially in a recession".

For agricultural development to succeed two factors are recognized as necessary :—

(a) the technology to raise yields, and

(b) the political will that agriculture should prosper and that means development and profits.

The start of the green revolution in India is interesting. The Monsoons failed in the late 60's when India was dependant on food aid and "quite content to farm the fields of Kansas!". The Suez Canal was closed by the Egypt-Israel War and India faced a seven-week gap in food supplies while cargo ships went round the Cape. Somehow food had to be moved from city stores to the countryside where people were starving without the townspeople rioting.

It is stated that the inherent insecurity and dangers of this situation were so well appreciated by the Indian Government that the decision was made to give food production priority even over industrialisation and to make that support consistent. This decision fortunately coincided with the introduction of the dwarf wheats from Mexico and the happy union of the required policy change with the needed technology made the green revolution become a reality. Neither alone would have sufficed. It may well be that our country is also just arriving at a similar crossroads where the right decisions are going to be of more than paramount importance. As a necessary postscript to the Indian story, it might be added that many Indian scientists are reported to have been opposed to dwarf wheats – which had to be developed at CIMMYT in Mexico – and not in India.

During the past two decades, the frequency and apalling severity of droughts in 41 sub-Saharan countries in Africa have been increasing. In 1978, a UN Conference on desertification concluded authoritatively that the Sahelian drought and the dismal plight of the affected countries were largely a man made phenomenon – being caused by deforestation, overgrazing and over cultivation; in short, different manifestations of over-population.

The tragedy of the situation is that while even in the seventies, sub-Saharan Africa had the highest rate of population growth, it is still accelerating whereas in all other developing regions it is tending to slow down. Infant mortality is still shockingly high – commonly approaching 200 per 1000 live births and life expectancy at birth is less than 40 years. Food production is increasing more slowly than in other areas. As a result, Africa is currently the only region where food production is lagging behind population growth.

Aware of the mounting problem and the plight of many millions affected and dying, several aid agencies and Sahelian Governments have striven to re-establish forests, to control the size of livestock herds and to replace the wasteful " slash and burn " method of shifting cultivation with more productive systems. All these efforts to little avail. Once the rot sets in, apparently to reverse it is near impossible. Almost every African government (and may others perhaps) depends for its survival on city dwellers – the civil servants, the police and the army. The price of food must therefore be as low as possible. Trouble is nobody has figured out how to support agriculture when it does not pay to grow food for sale, especially when raising the price of food is regarded as politically impossible !

Incidentally, the estimated area of land that degrades into " desert " annually is equal to 1 and 1/3 times the total area of Sri Lanka. 30 million square kilometres — over 20% of the Earth's land surface — and 80 million people who live on this land are under direct threat of desertification.

But what has all this to do with the plantation sector ? – you may well ask ! If you do so – this would concede me my first point ! For, the plantations have developed so much as a World apart that they seem much removed from hunger, food, people and farming – and have only to do with profits, exports and foreign exchange !

This has its historical roots in the manner in which the plantations evolved – spacially, organizationally, economically and sometimes even ethnically – isolated and distinct from the so called traditional sector. Perhaps the most serious consequence of this dichotomy is that the food crop sector, destined to directly serve local markets received far less than its due share of official support — in respect of inputs, research and extension services and assistance for development and in marketing its produce.

Does it not mean something that in spite of our favourable geographical location, climate, a rich agrarian tradition and an abundance of talent and expertise, — we are still globally classified as a low income, food deficit country ! A prominent recent visitor to the country drew attention to increasing malnutrition despite other impressive statistical indicators of national development.

Agricultural development under the colonial powers was marked almost in all cases by the installation of a non-food perennial tree crop. The produce was not for local consumption but was either an industrial raw material for finishing or a beverage ingredient needing further preparation. Examples are rubber, oil palm, cotton, sugar, coffee, cocoa and tea. Not even by accident would it seem that a food crop of short duration was introduced or encouraged. Whether by design or otherwise, the device introduced an element of inflexibility that has even ensured the unchanged continuation of production and trading practices. When the enterprise is at the same time large and economically of overpowering importance, it further ensures that modifications are minimal and that the essential weaknesses remain. Research conducted by our Institutes into improved preparation and presentation of product largely fails to approach these fundamental problems but rather to effect refinements only within a rigid and existing framework ! The 110 – pound tea chest, smoked rubber sheet and copra have been with us for over a century – only the measurements have undergone metric conversions !

One of the frustrations of Third World developing countries either their inability to conclude or to operate agreements bringing producers and consumers together. Tea is a classic example. Perhaps this is inherent and inbuilt into the systems governing post-production handling of the produce – a matter that might bear consideration. While norms and systems have continued unchanged for more than a century, critical examination of pricing systems reveal incongruities which must severely strain the credulity of producers.

When the plantations were being established in our country more than a century ago, the setting was decidedly less complex and more comfortable. Land was freely available in appropriate ecological regions, labour was cheap and procurable if not available, international competition was mild if existing at all and markets assured if not captive. Most importantly, the requisite inputs and resulting outflows passed largely through the same hands – and profits were therefore assured – if not on the swings, on the roundabouts ! The situation today is very different in all respects and further complicated by a population that is many times larger than it was then.

Independence also separated the producer from the market and thus produced a whole lot of new circumstances – Peter and Paul now becoming two distinctly separate entities !

Financial worthiness is obviously a central concern in agricultural investment planning. But it is not all – ecological and environmental stability and considerations of food security and social justice are increasingly entering into the reckoning.

Continuing inflation and an increased component of funds obtained under terms of commercial lending impose a serious temptation to devote such funds to plantation style development of export crops. This would seem to be the most direct route towards generation of convertible resources needed for debt servicing. The plantation system on a large enough scale might appear to be the most efficient way to grow the desired crops. This reasoning has been applied often – not infrequently in our own country. The difficulty is often that such an approach conflicts with the development objectives intended in the first place.

The involvement of financial institutions in the support of investment in developing countries has unleashed upon the placid agricultural scene, the whole new jargon and grammar of Economics ! This is bewildering to many an agriculturist who has hitherto been led to believe that agriculture is the business of blending together soil, climate, plants, animals, physical inputs and labour into a system which sustains the production of food and other necessities for humankind. He is now taught that it also concerns deploying money in such a way that it increases at a rate faster than if it had lain in a bank, outstrips inflation and when he eventually gets it, is capable of buying more things than if he had spent it in the first place. I doubt whether I have got it quite right !

What is somewhat alarming to the uninitiated is that in the related analyses, the final answer can often be heavily influenced by the initial assumptions – some of which could be quite arbitrary in the absence of hard and reliable data.

Perhaps my discomfort is typical of many like me who have come to be involved in the agricultural field without formal contact with what has since expanded into an important and all pervading discipline.

At the same time there has been what has been termed "a crisis in development thinking" which seriously questions the validity of economic considerations alone in determining the directions of agricultural development.

To quote such a contrary view, Geoff Tansey, a journalist specialising in food and agriculture issues says : "For too long, development has been dominated by economics – which seeks to guide the allocation of resources according to disputed formulas and dubious diagnoses. Economists, like the World's economic system, are in disarray."

Dealing with the reasons for the reversal of the food situation in many countries, Tansey lays the blame on export-oriented production and industrialisation strategies that have ignored the human costs. The result "... a situation where everyone is trying to minimise imports and maximise exports. Countries long able to meet their food needs have become dependent upon others for food while their export commodities face uncertain markets. Hunger and poverty have increased. The mythical trickle down from the rich to the poor doesn't trickle and when a squeeze comes it's the poorest who suffer most or die first."

What is here meant for individuals is equally true of countries and has led to the important formulation of the concept and spelling out of the means to achieving a "Global Food Security Strategy."

The article continues as follows : "This is perhaps not surprising when you look at the criteria for investment and change and the whole top-down notion of targetting. Investment must give a certain rate of return, usually in cash terms – so if you have poor people who need to produce things like food, for themselves first, it is difficult to get a rate of return considered adequate for investment."

The dilemma is heightened when funds for development have come from foreign loans. Then sufficient foreign exchange must be generated or saved to support repayment obligations. The pressure is then to invest in enterprises generating export income and again to ignore the local food sector which may in fact be deserving of the most urgent support.

There could be no doubt that the plantations have as large a role to perform in the future as they have in the past. It would however be unreal to suggest that all has been positive and it is my intention to suggest some directions in which some scrutiny might be desirable.

Tea rubber and coconut contribute a major share (60%) of the country's foreign exchange income. However, they obligatorily require a sizeable input of imports – principally fertilizers, fuels, agrochemicals, machinery and packing materials. There is a disquieting tendency to quote figures for gross earnings, overlooking foreign exchange expended in generating this income. It is true that some estimates made by concerned agencies have included this refinement, but there seems a need for more intensified studies into this aspect. Subsidised fertilizers, use of hydropower or firewood for generating motive power or for drying are some of the items which could lead to under-estimates if appropriate allowance is not made.

It is in the case of tea that the results of such studies could yield the most valuable information. If the picture alters substantially as a result, it may well influence expansion plans and investment patterns. This is a case for a joint study including policy making, producing and research agencies, to all of whom the information is vital.

Curtailment of production costs have been prime concerns of our research institutes. Perhaps in no other sector has this goal been more keenly pursued than in the field of fertilizer use. Factorial trials designed to evolve the best levels, frequencies and methods have dominated with a regrettable paucity of the " balance sheet" or recovery of nutrients type of approach.

Much more attention is desirable here if only for the reason that tropical tree crops can be expected to be relatively inefficient under field conditions. Field losses for tea are estimated to be of the order of 80% for nitrogen while they are perhaps even larger for rubber and coconut. No information exists for other elements. Such studies might shed considerable light in relation to cover and intercropping and suggest appropriate cultural measures such as mulching, covers or other practices. A further spin-off would be in providing leads for the use of wastes and by products as a means of returning nutrients to the field – an approach of particular promise for coconut.

Another subject which has forced itself on our attention is the matter of fuel – for motive power for processing and heat for drying of agricultural produce. Here again, the tea sector is of major concern. Just two decades ago, most tea estates were shaded over with trees – with the dual purpose of sheltering the tea and fuelling the factories. The view swept the plantations that the trees were holding back crop and were more profitably replaced by increased nitrogenous fertilizer. Coinciding with this was the " modernization " of factories by conversion to oil engines or hydropower. Subsequent developments have brought back the need to re-establish wood-lots and may in due time justify re-introduction of trees within the tea as well.

The environmental record of the plantations is probably less impressive than the financial. The older plantations, for reasons of availability and convenience were treated to choice sites – most probably hitherto under forest.

It is acknowledged that no farming system can match the profusion and protective effects of a forest cover. Given this however, rubber probably scores the highest marks in approaching closest to simulating a forest.

The debate on the causes of climatic change and the cause-effect relationship between trees and weather will long continue. The outcome in a sense is irrelevant. For, trees are a desirable component of the environment, fit unobtrusively into most settings and provide timber and firewood. Whatever form tree-planting and care takes – whether as tree-planting campaigns, forest reserves, watershed protection or fuel wood allotments, this activity deserves the strongest support. Once trees completely disappear – through ecological deterioration brought on by natural forces or human abuse – their re-establishment has proved time and again to be technically and logistically extremely difficult.

A striking effect of prolonged cultivation of tea lands has been the effect on soil pH. The potential insecurity of such soils is not adequately appreciated. At marginal values around 3·6, they are approaching the limits at which tea will grow. No other crop plant will tolerate these conditions either. Research should test these apprehensions and either dispel them or suggest corrective measures before the damage has become too severe.

At low pH, biological activity is very low, incorporation of organic matter is unsatisfactory and consequently water retentive properties and porosity decline. Little quantitative data is available except demonstrations of the extremely high erodibility of such soils. In such a situation it is no surprise that fertilizer efficiencies are low — as confirmed by analyses of silt from field drains which revealed exceedingly high contents of nitrogen.

A further index of impending troubles may be the extremely rare presence of earthworms in tea soils – even at rainfalls approaching 5000 mm !

The potential hazards of reduced rainfall, lessened percolation and consequent risk to dry weather river flows, silt movement into rivers and tanks and resultant fouling of irrigation systems are recognized and may require adjustments in the upper catchment areas – perhaps involving a sacrifice of some plantation area as an ecological necessity.

No reference to ecological abuse would be complete without reference to the smallholder sector. Where climatic conditions are marginal, topography steep and soil conditions fragile, smallholdings have generally been a disaster. For other than agronomic – but nevertheless important reasons – the smallholder plantation sector has been supported. This may be morally and politically defensible but raises serious doubts in regard to viability. The regular harvesting, processing and general maintenance needed by rubber and tea are major constraints. It could be argued that this makes them particularly appropriate for the small rural family unit. Experience however does not bear this out. The smallholder grew up during colonial times as a well to do local who, for reasons that had as much bearing to prestige as to economic necessity – set himself up to derive the benefits of what seemed the exclusive preserve of the expatriate operator. Denied the organizational skills, resources, knowledge and support, the results rarely matched the hopes. By the time of independence or even before, considerable extents and a sizeable contribution to total production had become realities and could no longer be ignored. Whole Departments and Corporations have been set up to service this category of holding. Coconut was of course always dominated by the smallholder.

While the smallholder unquestionably deserves and warrants support, an objective assessment is required of what such support should be – whether to be assisted to continue in a crop that is ill-suited to small scale operation or to be encouraged to diversify into production of some requirement for his own vicinity – and instead to be assisted in deriving an income for his effort that is not inferior to what his modest prior performance might have secured.

As a result of the series of food crises that have gripped a large number of poor countries – no less than 113, including 65 developing nations required food aid in 1982 – an increasing awareness has developed that a permanent solution could only come through strengthening of food production in the vulnerable countries themselves.

Largely through the initiative of the Food and Agriculture Organization, a Global Food Security Strategy has evolved which seeks to co-ordinate external assistance and national food production programmes into a coherent set of actions.

Food shortages are not occasioned only by natural disasters or gross environmental deterioration. They have also been brought about by insufficient positive actions and external problems like balance of payments difficulties which deny necessary inputs.

Fortunately Sri Lanka does not slot completely into any of these categories but has perhaps a trace of each element. At the present time, the need to ensure that a massive projected commitment to agriculture means the greatest benefit to the largest number justifies our concern for such developments.

A challenge lies in the possible need for a diversion of some of the limited resources and inputs to the production of food crops for the local market – even at the expense of cash crops for export where the ideal of adequately providing for both sectors may not be possible.

To add to what was already mentioned regarding the need to derive realistic values for net returns of foreign exchange from our export crops, some values – either for substitution or sale incomes – are probably already available. A checklist for what the nation needs in terms of cereals, subsidiary crops, milk, eggs, meat, paper, cotton, timber, firewood and so on as a probable first step in planning land use has also doubtless been drawn up.

We are fortunate in possessing information on land use possibilities and also a long history of investigation of farming problems in the regions earmarked for development.

Five central areas for attention have been identified in assuring an adequacy of food for all :

(1) Physical inputs
(2) Ecological responsibility
(3) Type of technology
(4) Storage, and
(5) Social aspects.

Physical inputs : Improved seed, fertilizers, water and on farm energy are four items which if they can be supplied without constraint – are capable of increasing production by as much as 30 times. The attainment of even a fraction of this potential would dramatically alter the position but is beset with enormous problems.

With the exception of rice and the export crops, Sri Lanka's record in genetic improvement of crops falls short of what could be expected. The progress of some other countries in the region – notably in relation to pulses, vegetables and fruit have been much more impressive. We may need to loosen our conservatism to procure more material with appropriate safeguards – for trial under our conditions.

High fertilizer prices and a dwindling of contributions to fertilizer assistance schemes are forecast to reduce availability. Cheaper forms, increased use of biological residues and concentrating on the more rewarding crops will be the main means for maximising returns.

Irrigation introduces twin considerations of water use economy and the avoidance of problems brought on by incorrect application. Large bodies of storage water that become available offer the potential for serious development of inland freshwater fishery resources.

The introduction, especially of tree crops (*e.g.* fruit, timber, pulp and firewood) into the higher reaches where water will be insufficient for rice or intensive annuals production.

Intensification of energy use is no longer being equated with tractors and petroleum driven machines. The contribution of human and animal energy is being more widely recognised. The importance of ensuring adequate supplies of wood as domestic fuel is seen as a serious need. Fast growing trees (*e.g.* Ipil Ipil, Casuarina, gums etc) are increasing in use and perform an additional purpose in restoring fertility to degraded lands as well.

A technology is growing for production of small scale units for electrical power generation from firewood. This blends neatly with expanding schemes for networks of communal woodlots in villages.

Ecological responsibility : Agricultural expansion often implies large scale clearing of forests. Thoughtless practices, especially in the Tropics could do serious damage. Where economic considerations permit, a stable system might consist of a patchwork of forests and cultivations – ideally on a very long-term rotation. The next best being a system of well placed reservations of sufficient extent.

The regularity with which foresters warn of impending disaster if action is not forthcoming to maintain a minimum forest cover is worrying. Forestry traditionally comes into conflict with the short term goals of agricultural development – and it is clearly time that more heed was paid to the demands of forestry – a further sustaining reason being that market forecasts for timber and pulp are good and needs for firewood evidently heading towards non-fulfilment. A major source of rural energy and ecological equilibrium depends on the active promotion of forestry.

The hazards of erosion, salinization and desertification are well known and their effects eloquently felt in many places. In addition to terracing, establishment of grasslands and trees, crop rotation, liming and grass leys as farming practices for soil restoration and conservation have received insufficient attention.

Type of technology — Appeasement of land hunger and the relief of urban population pressures are common objectives of schemes based on settlement of newly developed areas. The peasant will continue to be the primary intended beneficiary.

The type of technology suited to his situation and the means of getting it to him have proved immensely problematic.

Sri Lanka has tested various means to infuse the type of technology and skills that have nourished the plantations into the food production sector. The Special Leases Scheme, periodic efforts to stimulate food production on estates, Government and Co-operative Farms are some results which have been mixed and where efforts have seldom been sustained. The Agricultural Development Authority represents the most recent effort in that direction – and attempts to bring the kinds of services that the plantations have been accustomed to, to the peasant sector. It has probably been encouragingly successful.

It is tempting to expect that the plantation system – with a proven performance during more than a century and with superior management and production methods – is a suitable model for application to food production. It bears resemblances to the commercial farm which constitutes the basic unit for much of successful agriculturein the developed world. Having evolved within the country and not being an innovation suddenly being imported, it seems worthy of trial.

At a more particular and unobtrusive level, it is heartening to see growing numbers of skilled personnel who have been developed and schooled within the plantation system, turning to duties related to the peasant sector and food production.

Storage — One of the greater impacts of upgraded technology will be in quality improvement and reduction of spoilage and losses through better storage. One area in which our attitude has been almost cavalier is that of quality of produce meant for local use. Sri Lanka has much leeway to cover in the handling of perishables like fruit and vegetables. Simple methods for artificial drying of harvested grain and rat and insect-proof storage units for domestic use have been shown by experience to be superior to large centralised ones.

Research which has tended to concentrate on export crops needs to be applied at comparable levels to products for local markets as well. The situation has not changed entirely and now much research on problems confronting agriculture in developing countries is still conducted in research institutes of developed countries.

Social security — One of the great constraints to productivity of the peasant is believed to be insecurity of land tenure. Through Land Reform and other legislative measures and emphasis on colonization and settlement schemes, Sri Lanka is well ahead in overcoming this constraint.

The movement from subsistence agriculture to commercial production has apparently been rapid.

A fair number of price-stabilisation and support measures and assistance in marketing are being provided. Guaranteed price as a device for directing production in desired directions is possibly not being employed as effectively as it could be.

There are pitfalls in attempting to draw lessons from other countries and other situations. But long before the concept of global food security began to be articulated in words, it was being put into action in at least one country – China. Forced into it by various circumstances, this country adopted an inward-looking policy and aggressively worked towards positive solutions to their food and agricultural product needs – simultaneously with the adoption of a similar approach to industry. The results have been staggering – the country suddenly emerging as an important producer not only of rice, soyabeans and all of the other food needs of their one billion population – but also as a potential major producer of tea and rubber. This is probably the most striking recent example of the recognition of the correct priorities. World literature on agricultural development has been enriched by numerous studies on the Chinese experiment – in virtually every direction that the Global Food Strategy spells out.

In choosing my subject for this morning, I have been motivated by two recent personal experiences. During the past year or two I have had occasion to be in two countries – one in the Middle East and the other in – Africa South of the Sahara. Both have populations not very different from our own and land areas about 15 to 25 times that of Sri Lanka. One included the ancient land of Mesopotamia – which centuries ago was the most productive region of the Earth. Today it is miles and endless miles of desert and saline swamp. The country has no shortage of foreign resources to buy whatever food is required. The extreme vulnerability of their plight has surfaced dramatically by circumstances that have temporarily precluded the maintenance of this supply stream. The other country was a colony until 10 years ago. The entire preceding emphasis was on export crops – dependence on imports from the colonial power which were apparently adequate to sustain a reasonable standard of nourishment for the people. Today, a million starve – there simply is no food and much else besides. The misery and agony is indescribable and the destruction of every semblance of dignity through dependence on International Food charity is pathetic. We have no need to fear such disasters – but may be well advised to be warned.

I thank you for your patient hearing and once again express my thanks to Dr O. S. Peries and the Organisers for the great honour they have done me by inviting me to address this august gathering.

Session 1. PROPAGATION AND ESTABLISHMENT

INFLUENCE OF THE CROWNS IN TOPWORKED TREES OF *HEVEA*

By

CHANDRA SAMARANAYAKE, R. B. GUNARATNE AND L. S. KARIYAWASAM

(Rubber Research Institute, Sri Lanka)

ABSTRACT

There has been a renewed interest in crown budding because of the attractive possibility that crown budding may reduce wind damage losses, and reduce yield depression during wintering, while providing protection against leaf diseases. This was based on the idea that it was possible to retain the high yielding trunk by literally lopping off the undesirable top and replacing it with another crown which resists either wind damage or diseases or both. These effects are variable as the crown influences the growth, yield and latex properties of the trunk. The work discussed here indicates the importance of careful selection of trunk and crown combinations.

INTRODUCTION

Topworking or crown budding of *Hevea* was reported in 1926 when Cramer (1926) suggested that three component trees consisting of (a) an ideal rootstock (b) an ideal stem and (c) an ideal crown should be tried out to avoid as much as possible the seedling rootstock variability of a budded clone. De Vries (1926) worked on this suggestion and carried out two types of experiments where in (a) a combination of *H. brasiliensis* clones and (b) a combination of *H. brasiliensis* clones and other *Hevea* species were tried. These experiments indicated a dominant influence of crowns on the trunks but no definite conclusion could be drawn. Mass (1934) used three component buddings to overcome the susceptibility of certain clones to *Oidium* using LCB 870 as crowns in topworking. In South America topworking was used to obtain leaf blight resistant tops (Sorensen, 1942).

In Sri Lanka experiments on crown budding commenced in 1945 and LCB 870 was crown budded on to clones susceptible to *Oidium* leaf disease (Chandrasekera, 1980). However, this practice was later abandoned due to various shortcomings in this clone.

There was a revival of interest on crown budding in the South East in the late 1960's to overcome certain undesirable characteristics such as susceptibility to leaf diseases and wind damage in otherwise promising clones (Yoon, 1967). It was thought that it is possible to retain the high yielding portion of the tree (*i.e* the trunk) by literally lopping off of the undesirable crown and replacing it with another, which resists either wind damage or diseases or both. Experiments have shown that it is not always possible to retain the high yielding characteristics of the trunk by simply replacing its crown on growth, yield and other characteristics of the trunk (Rubber Research Institute of Malaysia).

Wind damage is not a serious problem in Sri Lanka and most of the recent selections are resistant or tolerant to leaf diseases that are common in Sri Lanka (Fernando, personal communication). However, it was of interest to study the effect of different trunk and crown combinations of some of the clones planted in Sri Lanka.

The work discussed here is from an experiment started in 1975 to study the effect of different trunks and crown combinations on growth, yield and raw rubber properties of latex removed from the trunk portion of the tree.

MATERIALS AND METHODS

Clones RRIC 45, 48, 101 and RRIM 600 which were to form trunk sections of the trees were budded on to illegitimate seedling rootstocks of clone Tjir 1 in a stock seedling nursery. Budded stumps thus prepared were planted in the field in June 1975 at an estate in the Kalutara District. The terrain is flat to gently undulating and the soil is red-yellow podsolic, boralu series (Silva, 1971). The field lay out was completely randomized with each experimental plot planted with 12 budded stumps.

Clones RRIC 117, RRIC 102 and PB 86 were used as crowns. Clone RRIC 117 was found to have a resistance rating of 2 for SALB (Fernando, personal communication), when tested at the RRIM, SALB unit, in Trinidad. This was the only clone available in 1975 which showed tolerance to SALB combined with a fairly appreciable yield. RRIC 102 has a high growth, vigour and a fairly high yield potential (Fernando, 1975). The four trunk clones were budded with three crown clones and with its own crown resulting in 16 trunk and crown combinations as shown in Fig. 1.

Growth

Girth of trees was measured annually, at a height of 90 cm from the graft union.

Yield

The trees were brought into tapping in 1982 on the ½S d/3 tapping system. Yield records were kept by taking two test tappings per month. On test tapping days latex from each tree was coagulated in the cup, the coagulated rubber was milled into lace, and air dried to constant weight.

Raw rubber properties

Samples, each of 100 ml were collected from each experimental plot, the pH was adjusted to 4·5 with formic acid, the coagulated rubber was milled, dried and the samples used in standard tests to determine raw rubber properties.

RESULTS

Growth

The mean girth of trunks starting from 1 year from crown budding is shown in Figs. 2, 3, 4 and 5. Growth of RRIC 45 trunks with different crowns showed that the girth of RRIC 45 trunks is improved by RRIC 102 crowns. RRIC 117 and PB 86 crowns behaved similar to its own crown (Fig. 2). Growth of RRIC 101 trunks were slowed down by PB 86 and RRIC 117 crowns, whereas RRIC 102 crowns had the same effect as its own crown (Fig. 3).

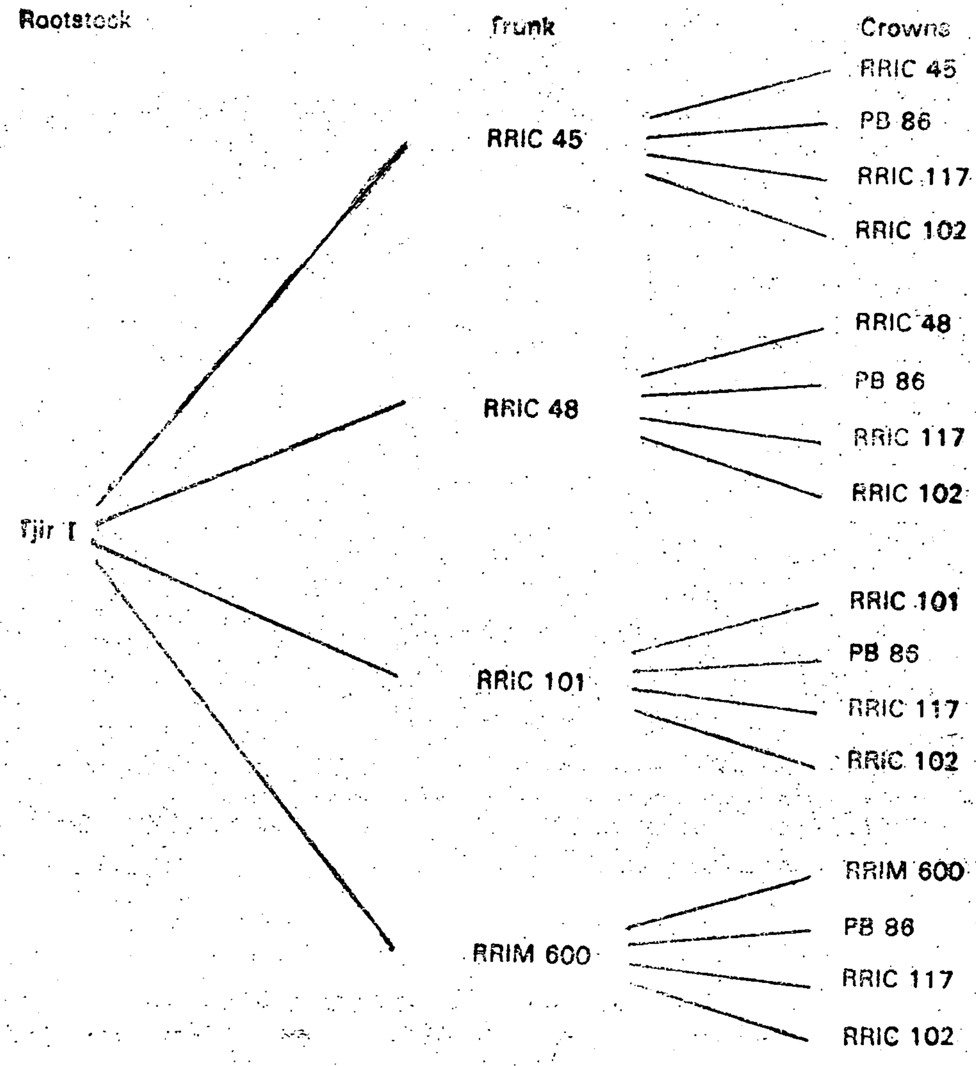


Fig. 1. Different trunk / crown combinations.

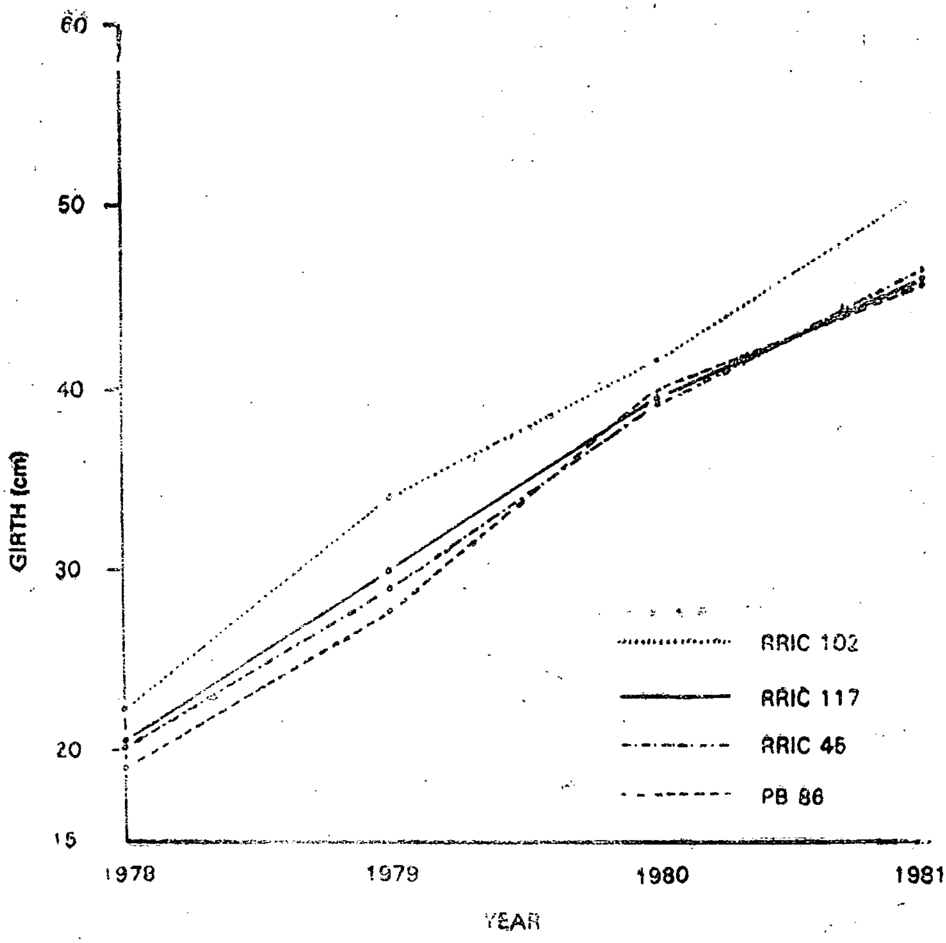


Fig. 2 Growth of RRIC 45 trunk with different crowns.

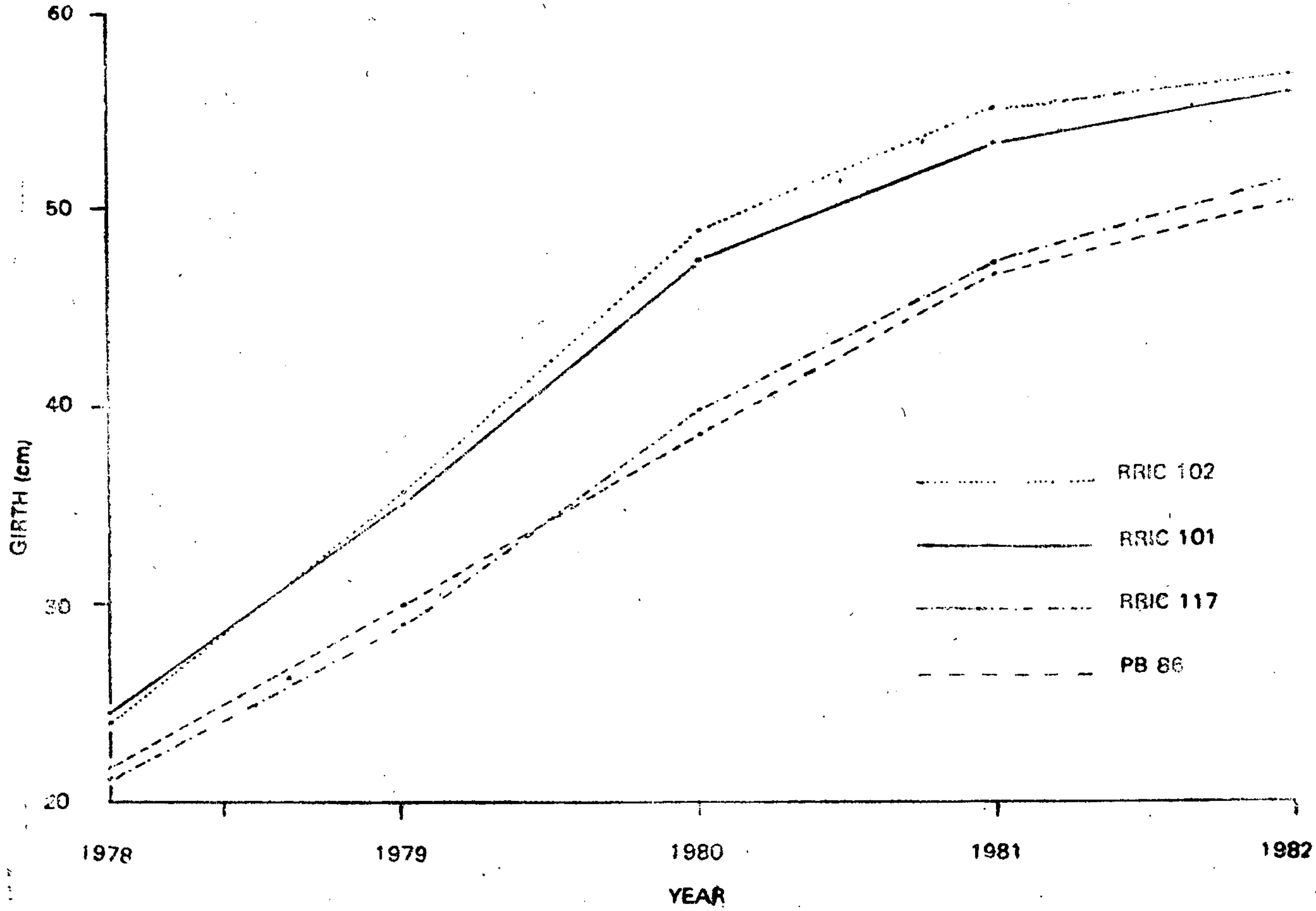


Fig. 3. Growth of RRIC 101 trunk with different crowns.

Similarly the growth of RRIC 48 has been reduced by RRIC 117 and PB 86 crowns, RRIC 102 crowns had a similar effect as its own crown (Fig. 4).

Growth of RRIM 600 was improved by RRIC 102 crowns whereas the other two crowns have not significantly influenced its growth (Fig. 5).

The percentage tappability at the time of opening of tapping cuts of each trunk/crown combination is given in Table 1. The effect of the crown on trunk growth is more clearly seen when the percentage tappability of different trunk/crown combinations is compared. The most dramatic effect was on RRIM 600, when crown budded with RRIC 117 and RRIC 102 the tappability was almost doubled.

Table 1. *Effect of the crown on % tappability*

Trunk	Crown						
	RRIC 45	**RRIC 48**	**RRIC 101**	**RRIM 600**	**PB 86**	**RRIC 117**	**RRIC 102**
RRIC 45	53	—	—	—	50	68	73
RRIC 48	—	89	—	—	25	36	68
RRIC 101	—	—	100	—	69	72	100
RRIM 600	—	—	—	47	31	83	87

Yield

The yield in g/t/t recorded for the second year in tapping of different trunk and crown combinations is summarised in Table 2. Yield of clone RRIC 101 is improved by RRIC 102 crown although the difference is not significant. Yield of clone RRIM 600 is significantly improved by RRIC 102 crowns.

Table 2. *Influence of the crown on yield*

Trunk	Crown	Yield (g/t/t)
RRIC 45	RRIC 45	18·1
	PB 86	23·2
	RRIC 117	18·9
	RRIC 102	22·2
RRIC 48	RRIC 48	20·1
	PB 86	19·7
	RRIC 117	16·1
	RRIC 102	25·5
RRIC 101	RRIC 101	34·9
	PB 86	30·9
	RRIC 117	30·8
	RRIC 102	41·6
RRIM 600	RRIM 600	21·6
	PB 86	18·0
	RRIC 117	21·0
	RRIC 102	29·4
	LSD	7·5

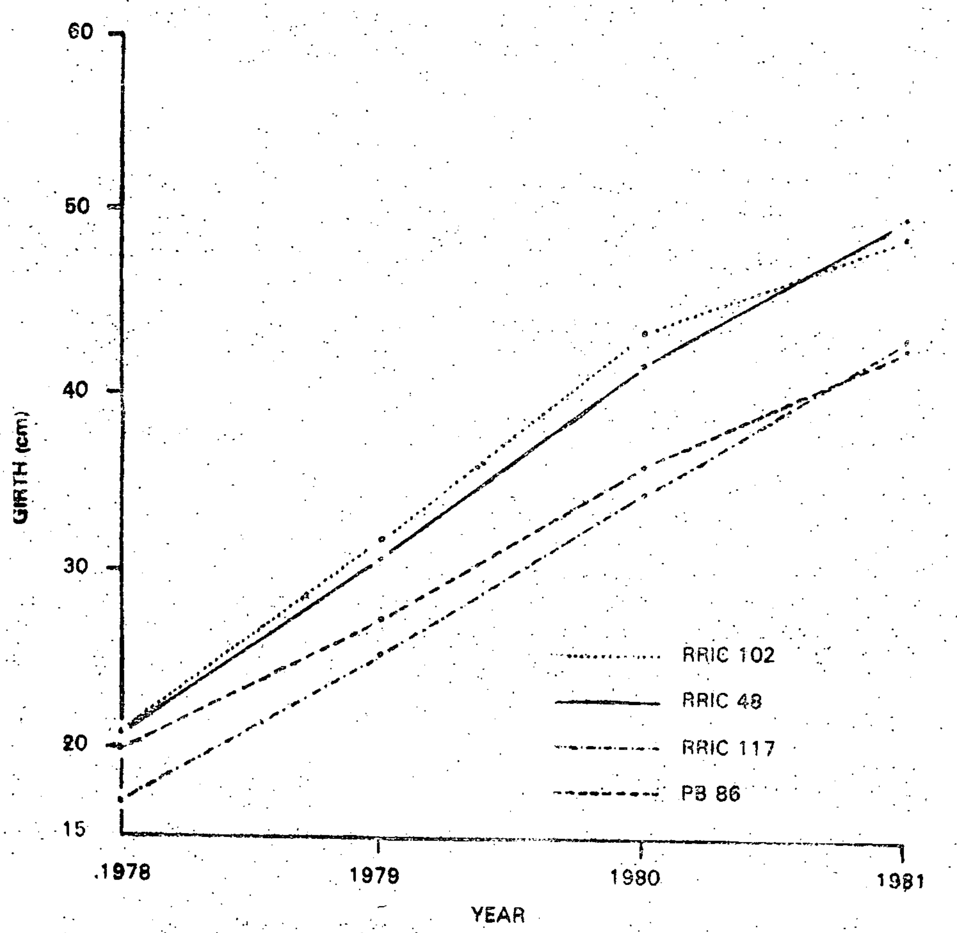


Fig. 4. Growth of RRIC 48 trunk with different crowns.

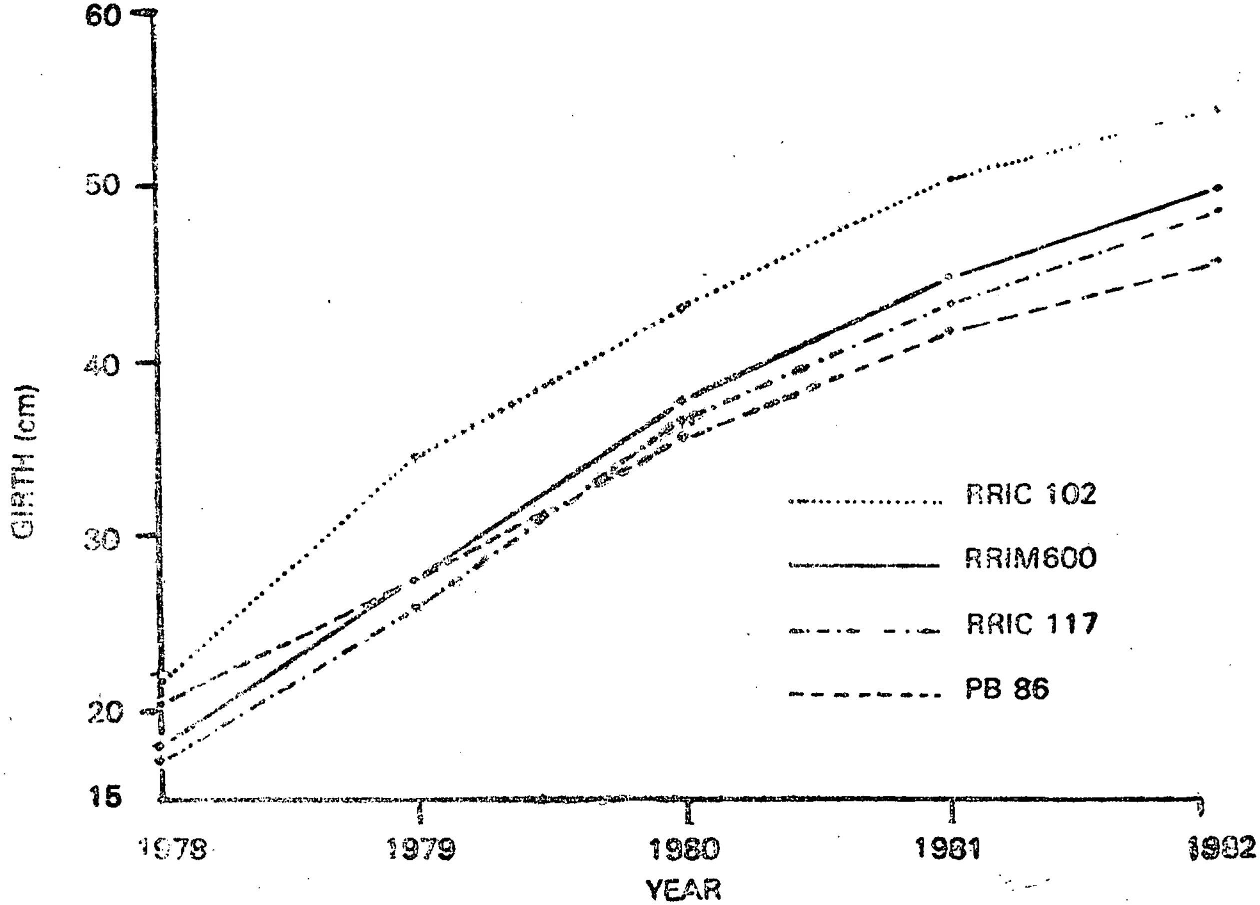


Fig. 5. Growth of RRIM trunk with different crowns.

Raw rubber properties

The mean values obtained for raw rubber properties of latex collected from trunk portions of the four clones with different crowns are summarised in Table 3. The ash content, N_2 content and PRI values did not show any significant differences due to the different crowns. Mooney viscosity and Wallace plasticity were increased in certain trunk/crown combinations and reduced in certain others.

Table 3. *Influence of the crown on raw rubber properties*

Trunk	Crown	Ash % wt	N_2 % wt	Mooney viscocity	Wallace plasticity	PRI	Colour
	RRIC 45	0·18	0·43	61·2	51·4	84·1	2·4
	PB 86	0·14	0·45	64·2	59·2*	82·7	2·7
RRIC 45	RRIC 117	0·13	0·43	57·8	50·2	83·9	3·1
	RRIC 102	0·13	0·42	67·5	61·4*	80·4	3·3
	RRIC 48	0·19	0·37	65·1	40·8	80·9	3·9
	PB 86	0·16	0·43	64·0	43·8	78·5	3·0
RRIC 48	RRIC 117	0·15	0·41	56·8	35·8	87·6	3·1
	RRIC 102	0·13	0·43	76·3*	54·4*	72·2	3·3
	RRIC 101	0·18	0·48	75·9	59·8	66·8	7·7
	PB 86	0·18	0·48	67·4	48·2	80·6	3·6*
RRIC 101	RRIC 117	0·16	0·46	59·1	39·0	81·5	7·1
	RRIC 102	0·12	0·41	70·4	51·6	75·7	5·2
	RRIM 600	0·17	0·47	56·5	38·6	82·3	2·5
	PB 86	0·17	0·48	65·1	46·4*	78·7	2·8
RRIM 600	RRIC 117	0·14	0·48	56·4	39·6	81·1	2·7
	RRIC 102	0·16	0·45	72·4*	50·6*	67·8	2·9
	LSD			10·8	6·3		1·8

RRIC 117 crowns have lowered the Mooney viscosity and Wallace plasticity in most of the trunk clones, but significantly only in RRIC 101. Clone RRIC 102 has increased the Mooney viscosity and Wallace plasticity in clone RRIC 48 and RRIM 600.

The colour index of raw rubber was also lowered significantly in latex of clone RRIC 101 crown budded with PB 86 and RRIC 102.

DISCUSSION

This study indicates that when a crown of a tree is replaced with another by topworking, the introduced crown influences the growth, yield and even the raw rubber properties of latex collected from the trunk portion. The effect of the crown on growth of the trunk is clearly seen when the tappability of the trunk portion under different crowns is considered. Crowns of RRIC 102 have improved growth of trunks of clones RRIC 45 and RRIM 600. The percentage tappability of RRIM 600 has been almost doubled with a RRIC 102 crown. RRIC 102 is itself a vigorous growing clone and its crown is capable of imparting its vigour to certain trunk clones. Growth of RRIC 48 trunks has not been improved by any crown other than its own. RRIC 117 crowns which are able to improve the growth of RRIC 45 trunks have suppressed the growth of RRIC 48 trunks. RRIC 102 which has improved the growth of RRIC 45 and RRIM 600 has suppressed the growth of RRIC 48. RRIC 102 crowns have on the whole improved yields of all four clones but significantly only in RRIM 600. In RRIC 48 where the girthing was depressed with RRIC 102 crowns, there is an improvement in yield. RRIC 102 crowns had the same effect on RRIC 101 trunks as its own crowns, resulting in 100% tappability at the time of opening of tapping cuts. However there was an improvement in yield of RRIC 101 trunks topworked with RRIC 102 crowns. Therefore the improvement in yield cannot be only due to the improvement in growth of the trunks due to the crown.

The influence of the crown on raw rubber properties is of great importance in that crowns can be used to improve the quality of rubber.

This study shows clearly that mere replacement of the undesirable crown with another is not sufficient to retain the desirable characteristics of the clone and to overcome the weaknesses due to the crown of a tree. Growth, yield and even the raw rubber properties of latex from the trunk are influenced by the crown. Therefore it is extremely important to study the influence of different trunk/crown combinations and carefully select crowns for the preparation of three-part-trees if the desirable characters of the trunk are to be retained or even improved.

ACKNOWLEDGEMENT

Our thanks are due to Mr W. N. Wickremasinghe, Biometrician for the statistical analysis of the data, Miss C. W. Ranasinghe for technical assistance, Dr P. A. J. Yapa, Head of Biochemistry Section and his staff for their help in the measurement of raw rubber properties.

REFERENCES

CHANDRASEKERA, L. B. (1980). Crown budding with clone LCB 870, *Rub. Res. Inst. Sri Lanka Bull.* **15**, 24 - 27.

CRAMER, P. J. S. (1942). Oude vrieuden en nieuwe Keunissen in den Cultuurtuin. *De Bergcult.* **16**, 134 - 142.

MASS, J. G. J. A. (1934). De selectie van *Hevea brasiliensis* bijs lands Caoutchoucbedrifj Archf. *Rubbercult. Ned. - Indie.*, **18**, 58.

SORENSEN, H. G. (1942). Crown budding for healthy *Hevea. Agriculture in the Americas.* **2**, 191 - 193.

VRIES, O. de (1926). Superiour plant materiaal. *De Bergcult.* **1**, 404 - 410.

DISCUSSION

Q — RUBBER BOARD INDIA : RRIC 102 seems to have the best crown compared to other clones tried. Is the canopy of RRIC 102 denser in comparison to other clones. Can you please clarify,

A — A. C. I. SAMARANAYAKE, (RRISL) : RRIC 102 is a very vigorous grover. It has a fairly large canopy. But we have not done a detailed study of canopy sizes in any of the clones tried in this experiment.

Q — ESAH YIP, RRI Malaysia : In the study of effect of crown on raw rubber properties, apart from Wallace plasticity and Mooney viscosity have you studied any other properties of raw rubber and if so have you noticed any particular trend in the effect of crown budding ?

A — A. C. I. SAMARANAYAKE, (RRISL) : Besides Mooney viscosity and Wallace plasticity we studied ash content, nitrogen content, plasticity retention index and colour. There was no significant difference in ash content, nitrogen content and PRI due to crown budding. There was a significant difference in colour index in RRIC 101 crown budded with PB 86 and RRIC 102.

Q — When you say there is no difference due to the crown did you look to see the nitrogen content of the crown clone as a trunk clone in comparison or just the effect of the crown on which ever the trunk is ?

A — Here we have compared the effect of the introduced crown with its own crown on different raw rubber properties. We have also studied the crown latex, these studies are still in progress.

THE ROLE OF CUTTINGS AND CLONAL ROOTSTOCKS IN *HEVEA* CULTIVATION

By

S. K. LEONG AND P. K. YOON
(Rubber Research Institute of Malaysia, Kuala Lumpur)

ABSTRACT

Cuttings of Hevea *can be rooted by mist propagation. In the absence of a taproot, the root system is unstable. Pseudo-taproot induction and deep planting were attempted to overcome this problem. The possible establishment of budgrafts on rooted cuttings allows for the study of stock/scion combinations using clonal rootstocks. This paper reviews earlier developments of work at the Rubber Research Institute of Malaysia on cuttings and clonal rootstocks and presents recent results from field trials with these materials.*

INTRODUCTION

The current conventional method of propagating clones of *Hevea* is by budgrafting on to seedling rootstocks. Effect of rootstocks in improving scion growth and productivity is considerable but a certain amount of heterogeneity is still traceable to rootstock effect. If some of the desired rootstock effects are to be perpetuated, propagation of clonal rootstocks should be attempted.

There are distinct advantages and possibilities in the use of cuttings and clonal rootstocks of *Hevea*. However, the problem of absence of taproots in rooted cuttings contributing to instability, has to be overcome before cuttings are acceptable for use in rubber cultivation. The possible establishment of budgrafts on rooted cuttings allows for the study of stock-scion combinations using clonal rootstocks. This paper reviews work carried out on the developments of cuttings and clonal rootstocks in *Hevea* (Yoon & Leong, 1975; Leong, *et al*, 1976) and presents up-to-date results on their performance in the field.

MATERIALS AND METHODS

Mist propagation and rooting of cuttings

Mist propagation is an essential prerequisite for the rooting of cuttings of *Hevea*.

The mist system must distribute water evenly over the cuttings and replaces just about the same amount of water evaporated and drained off.

A pump may be necessary to raise the pressure required for efficient atomisation of water from 0700 to 1800 hours daily.

A well-drained and aerated medium like washed river sand provides for a proper oxygen-water balance during the process of root initiation of cuttings.

Cuttings are prepared for rooting by detaching fully hardened terminal shoots from the source bush and treating the trimmed ends with fungicidal powder before inserting into the sand-bed.

Hardening-off process

The hardening-off process is essential as an after-care of rooted cuttings to establish them on their own roots. Three methods have been tried :

Mist nozzle has been the conventional method used.

Sprinkler irrigation is more effective in terms of unit cost and effective coverage of mist spray.

Use of shade and antitranspirants suggests that mist may be substituted by shade to a considerable extent if combined with antitranspirants to reduce transpiration of the rooted cuttings.

Pseudo-taproot induction

Several approaches were adopted to induce and enhance pseudo-taproot formation :

Pre-rooting induction by methods of cutting and placement in sand-bed and by the use of polythene tubing on the cut ends.

Post-rooting manipulation by selective root pruning to one or two roots.

' High level planting ' which reduces the regeneration problem, allowing production of a stronger pseudo-taproot.

The most effective method combines root pruning to one and ' high level planting '.

Establishment of scions on clonal rootstocks

Several methods were investigated to establish scions on clonal rootstocks :

Budding on rooted cuttings involves budgrafting on the new stem growth followed by high cutback and isolation groove above the budpatch.

Budding of shoots on source bush involves budgrafting scions on to the stock source bush *before* severing the shoots at various stages of development for subsequent rooting under mist.

Clonal rootgrafting involves grafting a detached clonal root piece obtained from rooted cuttings on to shoots which may be detached or still be intact on the source bush.

The two field trials discussed later were established by the first method of budding on rooted cuttings.

RESULTS

Performance of cuttings

The nature of the root system in cuttings was studied by excavating mature plants in the field. Fig. 1 shows a typical clonal cutting with multiple lateral roots and the conspicuous absence of a taproot. Fig. 2 shows that induced pseudo-taproots can be produced but they are fairly weak. The results of success are also inconsistent. In many cases, strong positive geotropism is not attained, confirming observations in the previous paper (Buttery, 1961). In consequence, the induced pseudo-taproot deviates on hitting any hard surface and may curve up as shown in Fig. 3.

Recognising the absence of a good pseudo-taproot with strong positive geotropism, cuttings were planted at different depths in the ground. Excavation of these plants shows that the stem portion of cuttings which were deep planted have not produced any new adventitious roots (Fig. 4). This differs from deep planting seedling stems which produce good laterals (Yoon and Ooi, 1976 & 1978). However, lateral roots from the buried stem portion of clonal cuttings may be induced by making V-cuts with pebbles inserted just before field planting (Fig. 5).

The subsequent growth of cuttings with pseudo-taproot arising from root pruning was assessed in an experiment which compared this with normal cuttings planted at various depths in the ground. Girths at opening of RRIM 600 and RRIM 623 are shown in Table 1. The results show that the root pruning originally carried out to induce pseudo-taproot has no adverse effects on the growth of the cuttings. The results also show that deep planting does not retard growth, as was demonstrated previously with seedlings and buddings (Yoon and Ooi, 1976 & 1978). No wind damage has occurred in the whole trial.

Table 1. *Girth of cuttings at opening for tapping*

Treatment	Girth (cm) RRIM 600	Girth (cm) RRIM 623	Mean	
Cutting	37·7	46·1	41·9	
Cutting with deep planting	39·8	47·0	43·4	±1·27
Cutting with pseudo-taproot	39·9	46·9	43·4	
Mean	39·1	46·7		
	±1·04 (3·77)			

Clonal stock-scion interaction studies

Experiment 1 which studies clones PB 5/51, RRIM 623 and RRIM 600 as both clonal rootstocks and scions in all possible combinations has reached maturity at 5 years after planting. Analysis of yearly girth results shows no evidence of stock-scion interaction. The slowest growing scion is RRIM 600. The other two scions are similar in vigour. Averaged over the three scions, the best rootstock is PB 5/51 followed by RRIM 600 and RRIM 623 which are similar in vigour (Fig. 6).

Experiment 2 studies scions of PB 310, RRIM 701 and RRIM 600 on seven clonal rootstocks. Statistical analyses again show no stock-scion interaction. Again, scion, RRIM 600 is the least vigorous with PB 310 and RRIM 701 being similar in vigour. As illustrated in Fig. 7, which shows the pooled averages of the three scions, the best rootstock is PB 5/51. This is followed by PB 250, RRIM 623, RRIM 600, *H. spruceana*, PB 5/51 × *H. spruceana* and PB 5/51 × *H. pauciflora* in order of decreasing vigour.

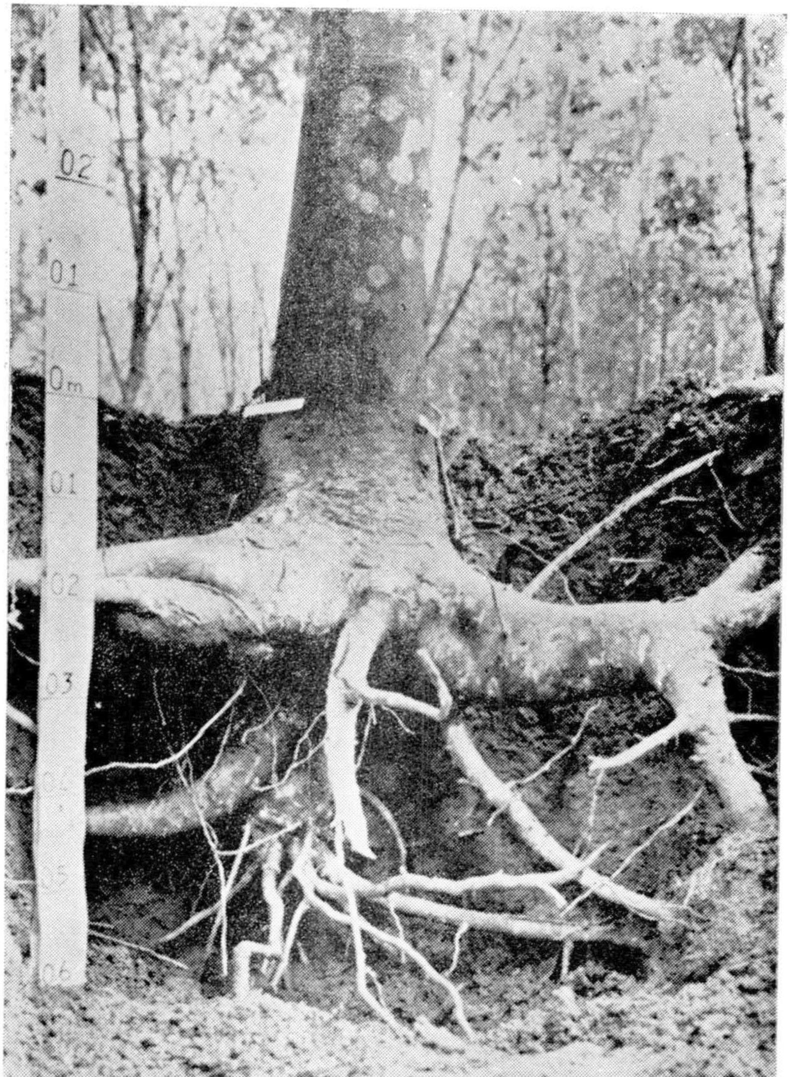


Fig. 1. Typical clonal cutting with laterals and lack of taproot.

Fig. 2. Cutting with induced pseudo-taproot.

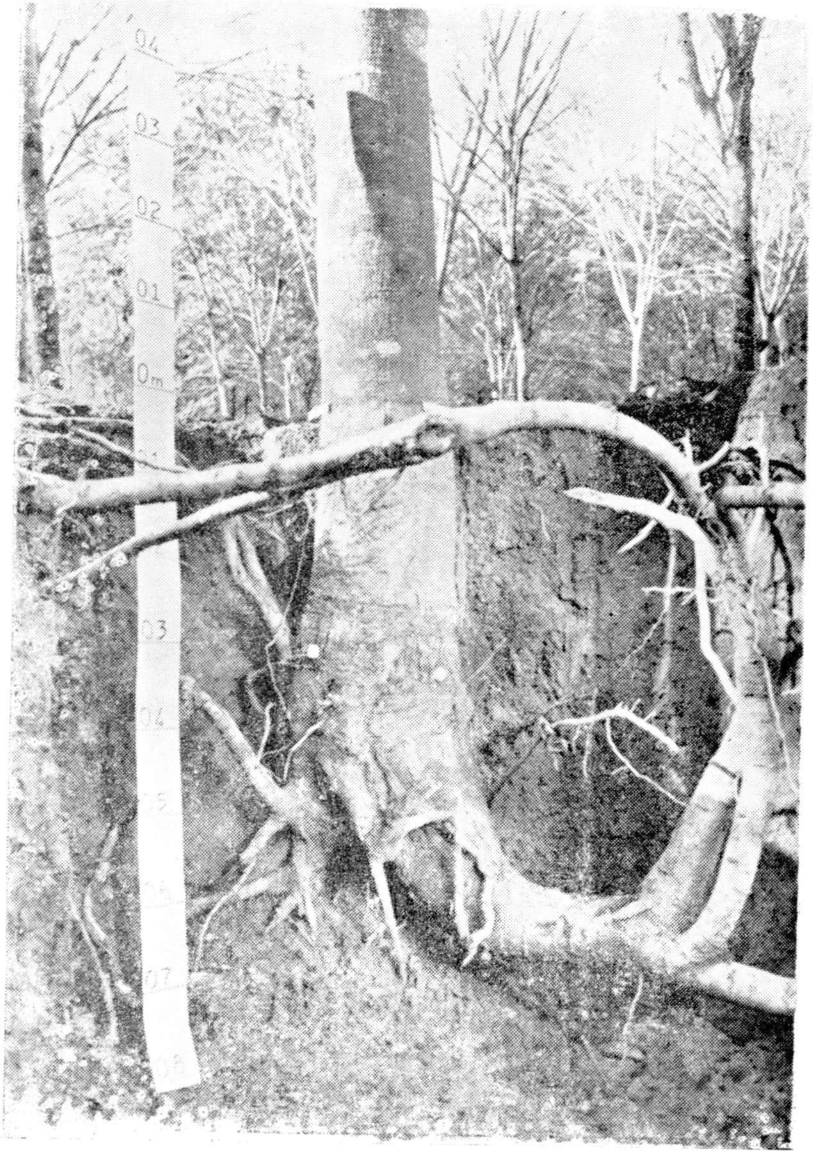


Fig. 3. Behaviour of pseudo-taproot showing poor positive geotropism.

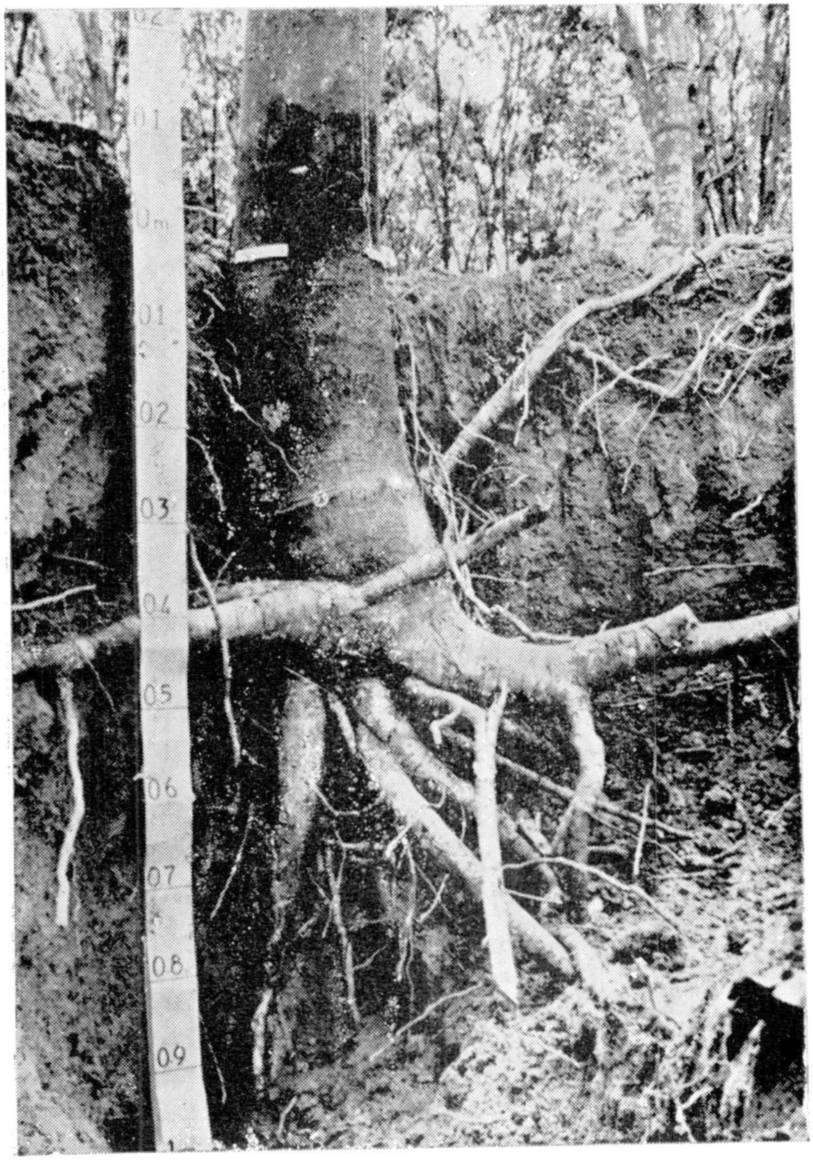


Fig. 4. Cutting with deep planting showing lack of adventitious roots from buried stem.

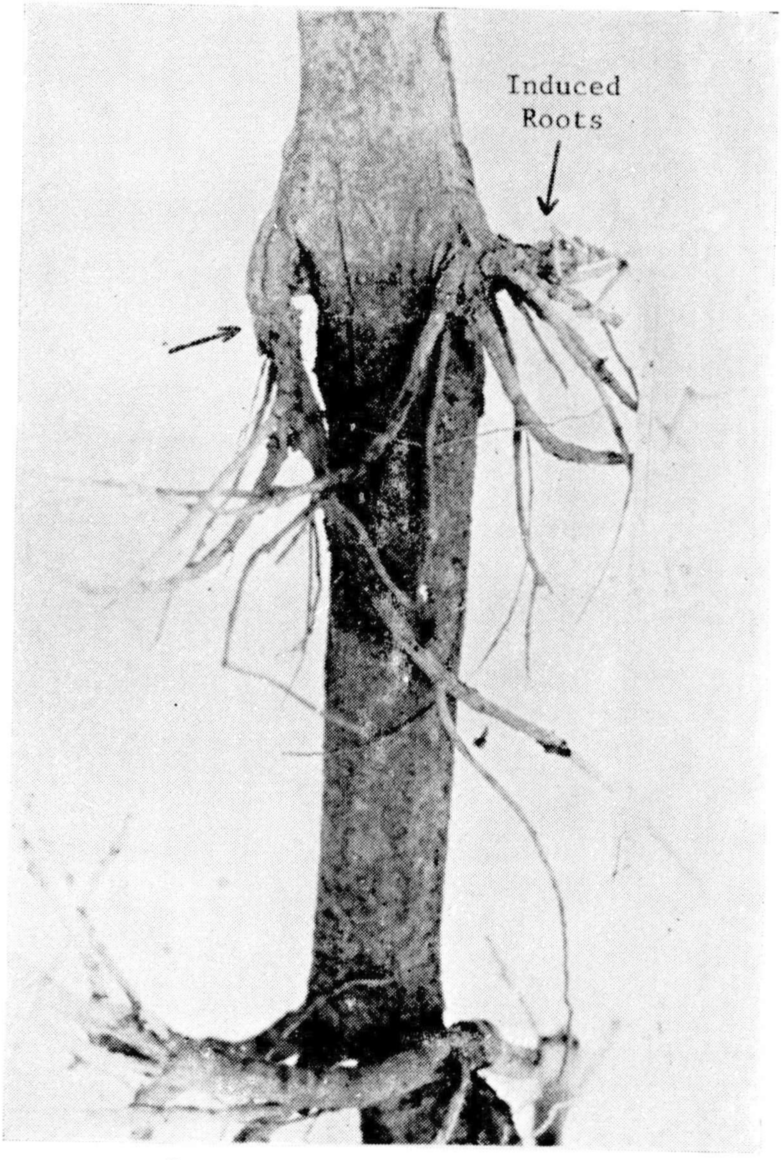


Fig. 5. Root induction by V-cuts in cutting.

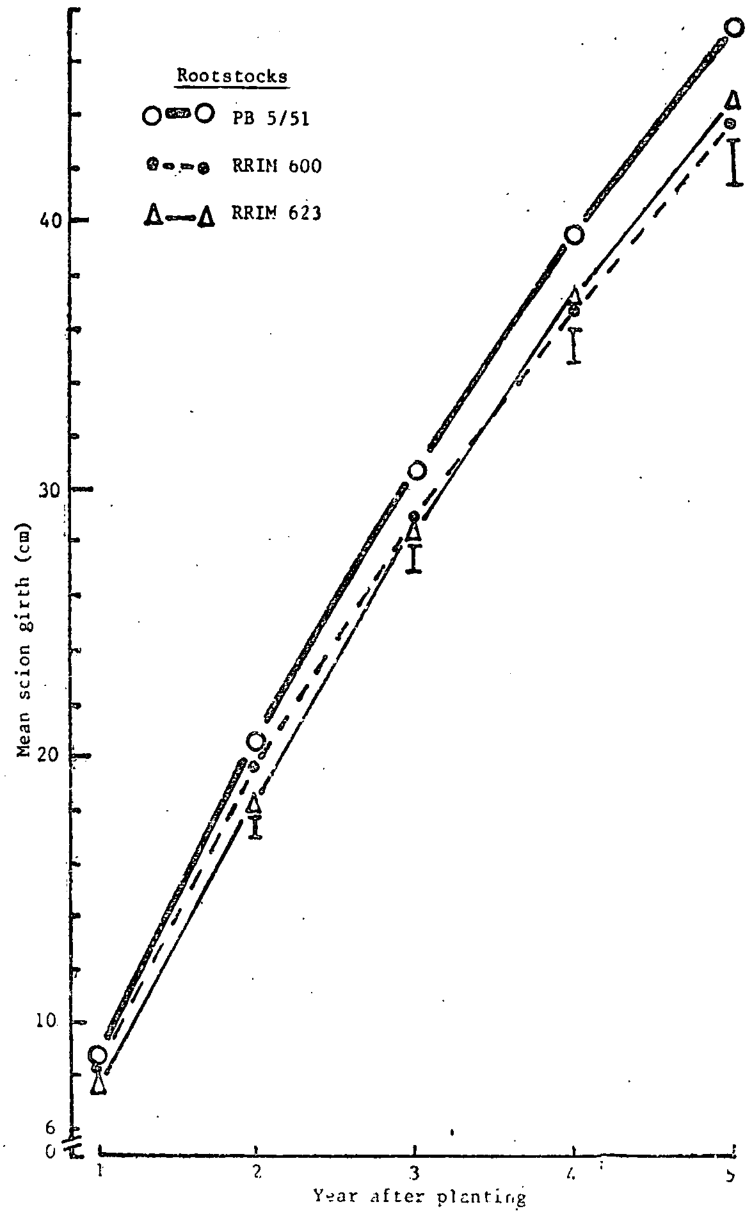


Fig. 6. **Experiment 1 : Effect of clonal rootstocks on scion growth**

ON SCION GROWTH

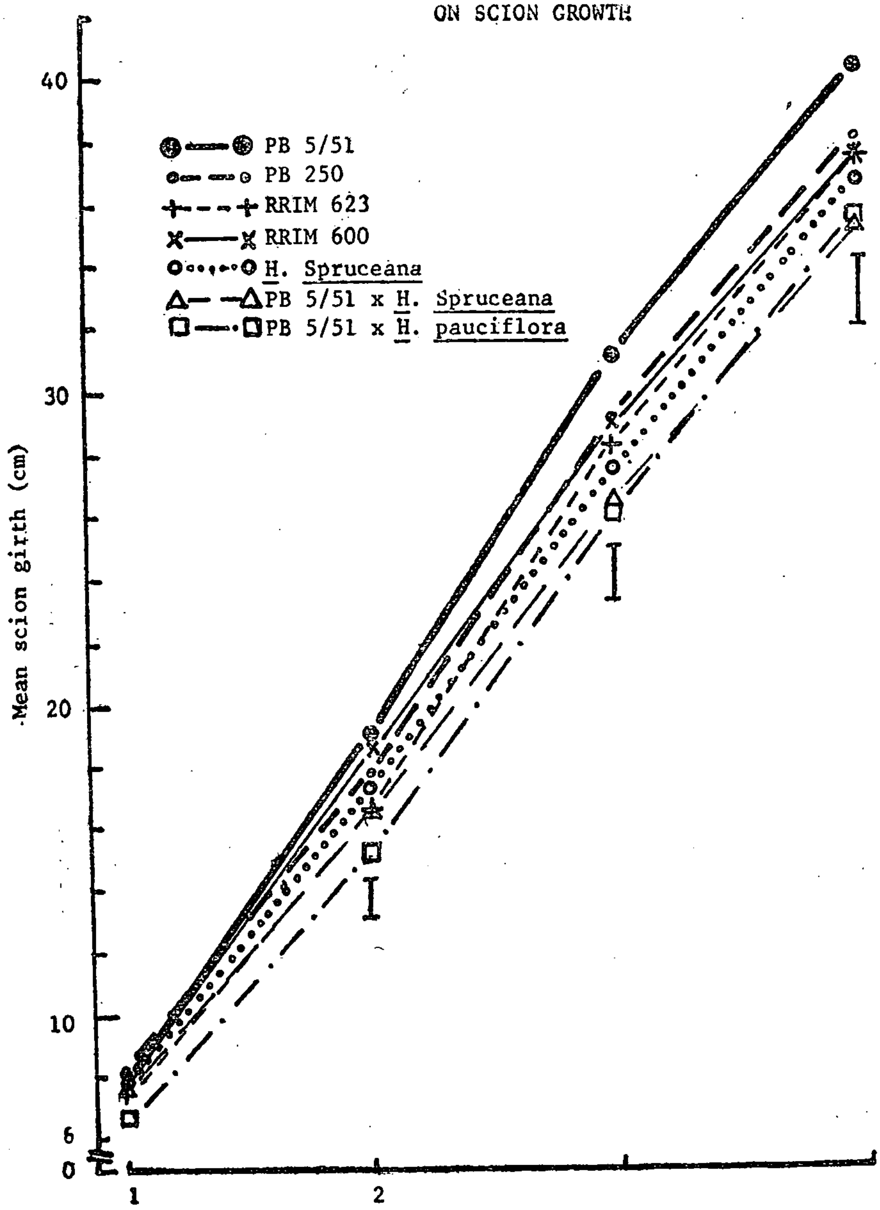


Fig. 7. Experiment 2: Effect of clonal rootstocks on scion growth

DISCUSSION AND CONCLUSION

The results have demonstrated that induction of pseudo-taproots may not be promising because of inconsistency in the production of these pseudo-taproots, as well as in their poor positive geotropism which confirms earlier findings (Yoon & Leong, 1975). While deep planting with cuttings have shown no adverse effects on growth, it has also not proven that such deep planting would reduce the instability problem as the trial as a whole has not suffered any wind damage. The lack of laterals from the buried cutting portion may be overcome by root induction. This, together with deep planting, may contribute to a more stable root system.

Results of stock-scion trials at the Rubber Research Institute of Malaysia using monoclonal and polyclonal mother clone seedling rootstocks have shown significant effect of rootstock on scion girth and yield (Ng, *et al*, 1981, Ng & Yoon 1982, Ng, 1983). Use of monoclonal seedlings is an improvement over the early stock-scion trials using illegitimate seedling families (Paardekooper, 1954; Buttery, 1961). However, certain shortcomings still exist because of heterogeneity of the stocks. The desirable mother clone seedling rootstocks are not completely reproducible.

At the RRIM, most of the problems associated with the difficulty of budding on rooted cuttings have been resolved, enabling various stock-scion combinations to be established. Results from two experiments are encouraging and have shown that the best performing clonal rootstock is PB 5/51. Earlier findings using monoclonal mother clone seedling rootstocks, which are heterogenous, also showed PB 5/51 to be the best seedling rootstocks (Ng; *et al* 1981; Ng and Yoon, 1982; Ng, 1983).

Experience from breeding and selection work has indicated that polyclonal seedlings, being hybrid in nature, could out-perform monoclonal seedlings. However, work in the RRIM has shown that RRIM 623 polyclonal rootstock performs worse than RRIM 623 monoclonal rootstock (Ng, *et al* 1981; Ng, 1983). It is now found in experiment 2 that the least vigorous clonal rootstocks are PB 5/51 × *H. pauciflora* and PB 5/51 × *H. spruceana* despite the fact that they share the common mother clone PB 5/51 which performs best as mother clone seedling rootstock or clonal rootstock. This finding raises doubts about using polyclonal mother clone seeds as rootstocks. It reinforces our view that if polyclonal seedling rootstocks are to be used, they should only be from seeds obtained from boundary trees with another clone superior in yield and vigour (Ng, 1983). Use of monoclonal seeds, while overcoming this problem, may still give rise to possible heterogeneity and non-uniformity. The use of clonal rootstocks would considerably reduce these possibilities as they have better uniformity and are reproducible by vegetative propagation.

ACKNOWLEDGEMENT

The authors wish to thank Dato' (Dr) Haji Ani bin Arope, Director of RRIM, for permission to publish this paper. The capable technical assistance of Messrs. A. Kumarasamy, Gerard Sta Maria, H. T. Leong and Mrs H. K. Phun are gratefully acknowledged. Thanks are also due to Mrs P. W. Cheng and Mrs H. L. Lew for the typing.

REFERENCES

BUTTERY, B. R. (1961). Investigations into the relationship between stock and scion in budded trees of *Hevea brasiliensis J. Rubb. Res. Inst. Malaya*, **17**, 46.

LEONG, S. K., OOI, C. B. AND YOON, P. K. (1976). Further development in the production of cuttings and clonal rootstocks in *Hevea. Proc. Natn. Pl. Propagation Symp. Kuala Lumpur 1976*, 154.

NG, A. P. (1983). Performance of rootstocks. *Plrs' Bull. Rubb. Res. Inst. Malaysia* No. **175**, 56.

NG, A. P., SULTAN, M. O., YOON, P. K., HO, C. Y. AND OOI, C. B. (1981). Influence of six rootstocks on growth and yield of six scion clones of *Hevea brasiliensis. Proc. Rubb. Res. Inst. Malaysia Plrs' Conf. Kuala Lumpur* 1981, 134.

NG, A. P. AND YOON, P. K. (1982). Relationship between rootstock and scion in *Hevea brasiliensis* Muell Arg. XXIst Inst, Hort. *Congress Hamburg, F. R. Germany, Abstract*, **1**.

PAARDEKOOPER, E. C. (1954). Resultaten van twee onderstamproeven bij. *Hevea De Bergcult*, **23**, 551.

YOON, P. K. AND LEONG, S. K. (1975). Induction of pseudo-taproots of cuttings and production of clonal rootstocks in *Hevea. Proc. Int. Rubb. Conf. Kuala Lumpur* 1975, II, 85.

YOON, P. K. AND OOI, C. B. (1976). Deep planting of propagated materials of *Hevea* — its effects and potentials. *Proc. Natn. Pl. Propagation Symp. Kuala Lumpur* 1976, 273.

YOON, P. K. AND OOI, C. B. (1978). Prospects of deep planting of propagated materials of *Hevea. Int. Rubb. Res. Dev. Bd. Symp. Kuala Lumpur* 1978.

DISCUSSION

Q — ABDUL MAJEED, RRI Indonesia : Particulary for the next planting season we need lots of seeds for planting hundred thousand ha of rubber. So I wonder whether the Author is experienced in planting under different soil texture, what I mean is how this structure alters the structure of the rooting system.

A — S. K. LEONG, RRIM : I do not think you are correct Dr. Majeed, if you are saying that there is any difference in the root system in different soil types. We have not established clonal rootstock on the various types of soil at the moment. But behaviour of the pseudo-taproot as I have shown in the slide, did show that if there are hard pans in the soil some of these tend to be diverted upward even though they may go down a certain distance in the ground.

Q — JOHN GNANARATNAM, JEDB : Have you tried out different rooting media for rooting of rubber cuttings. If so what is the best type of rooting medium which has given the highest percentage of success.

A — S. K. LEONG, RRIM : The cuttings are left in the sand basin in the mist frame, so the best rooting medium is actually washed river sand, because this has good aeration and drainage for the initiation of roots.

Q — JOHN GNANARATNAM, JEDB : What is the light intensity that should be prevailing at the time of rooting.

A — S. K. LEONG, RRIM : During the rooting of cuttings we actually put them under a roof and light. Or else you can have very little shade by hessian. We use hessian to provide some degree of shade, for rooting of cuttings. But when the cuttings are being hardened, this we have done in full sunlight.

Q — JOHN GNANARATNAM, JEDB : What is the percentage of humidity that should prevail at the time the cuttings are been rooted.

A — S. K. LEONG, RRIM : I think because we do not do root cuttings in an enclosed atmosphere this is not so important and we have not monitored this. If we have enough sunlight and good drainage, and atomisation is efficient, then the rooting will occur.

Q — JOHN GNANARATNAM, JEDB : Have you come across different percentage of rooting in different clones. Is there a particular clone that gives highest percentage of success in the rooting bins.

A — S. K. LEONG, RRIM : I have shown a table of rooting ability of clones. Good rooters can have rooting ability of over 90%, poor rooters low as 3% or even 2%. At the RRIM we also use rooting, hormones to help the rooting of these poor rooting clones.

Q — JOHN GNANARATNAM JEDB : In tea we have polythene sheet covers right over the surface of cuttings. Have you tried this system in the rubber cuttings. Also the polythene covers come in direct contact with the leaves.

A — S. K. LEONG, RRIM : We do not think this is necessary in rubber cuttings and if you use polythene sheet there is quite a big build up in the temperature which is not good. Tea would root in a shorter time where as rubber takes 7 - 9 weeks for rooting, and they will not perform so well if they are covered up.

Q — M. J. CAMPAIGNOLLE, IRCA : Many years ago we have planted trees by cuttings of PB 86. Some of these trees fell down others are still living, and they are now very big trees. When we looked at the roots of these trees we saw that there were big irregularities. Do you think there is a big clonal difference in the way, in which roots grow in rooted cuttings.

A — S. K. LEONG, RRIM : We believe that there will be differences between clones in the root system. The rooted cuttings normally get wind blown during the 2nd 3rd years from establishment. We have also noticed that when they pass this stage they can remain in the ground and when we look at the mature root system we find that the adventitious roots are very pronounced and many strong roots grow downwards from these laterals.

EMBRYOGENY AND ORIGIN OF ANTHER PLANTLET OF *HEVEA*

By

WANG ZEYUN, WU HUYE, ZENG XIANSONG, CHEN CHUANQIN, LI QIONGYING
(*Rubber Research Institute, South China Academy of Tropical Crops, China*)

ABSTRACT

Histological and cytological observations on slices from continuous sectioning of the whole anther in culture at fixed intervals, showed that callus could be derived from parenchyma cells at the cut end and apex, and in the septum and wall of the anther. The pollen grains in the anther disintegrated and died shortly after inoculation. It was observed that only four of the 12079 pollen grains observed, divided once or twice before their death.

All embryoids originated in the cells in the peripheral layer of the somatic calli established. The period between the 39th – 49th days after culture saw quick aging of the calli and the development of prolific embryoids. The number of chromosomes in calli, embryoids and plantlets were examined. The results revealed that 91·8 – 95·6% of the total cells at division phase contained 28 – 36 chromosomes, indicating that they were diploids. The phenotypical features of the anther plants also proved that they originated from somatic cells.

INTRODUCTION

Studies on *Hevea* explant culture have been in progress in the Rubber Research Institutes of the principal rubber growing countries of the world, such as Malaysia, Indonesia and Sri Lanka as well as in Britain and France (Annual Report RRIM, 1971 – 79 ; Ghandimathi & Paranjothy, 1975 ; Wilson & Street, 1975 ; Carron & Enjalric, 1982 ; Anon, 1982). They concentrate their efforts either on anther culture or on tissue or organ culture. The main purpose for the induction of pollen plants is to obtain homozygous lines, by which new varieties may be obtained through crossing. The induction of somatic plants on the other hand aims mainly at eliminating the adverse influence or rootstock on yield, cold hardiness and disease resistance of scions, so as to confer on the plants derived from somatic cells of anthers from clones all the merits possessed by seedlings. This will enable the plants to be used as planting materials of a new type in commercial scale. During the period of 1978 – 1979, we carried out some investigations on the histology and cytology of the *in vitro* anthers in culture with the object of improving the culture efficiency and judicious application of the anther plants. Later on, some observations were followed on the phenotypical features of the plants.

MATERIALS AND METHODS

The materials used were anthers from clone Haiken 2, a variety of *Hevea brasiliensis*, Muell-Arg. The anthers were inoculated when the majority of their pollen were at the uninucleate stage with a few at dicaryotic phase.

Three treatments were laid out (Table 1). The culture media were autoclaved, and the temperature of the culture room was controlled at 25 – 28°C. Natural diffused light was provided at the stage of induction of callus and embryoids while a daily 14-hour illumination with fluorescent lamp was given at the stage of induction of plantlets from embryoids at the intensity of 2500 lux.

Table 1. *Treatments in the experiment*

Number	First medium for inducing callus and mini embryoids (mg/l)	Inoculation
1	MS* + 2, 4-D_1 + CM5%, Sucrose 10%	Immediately after flower picking
2	MS** + 2, 4-D_1 + NAA_2 + K_1 + CM 10% + Sucrose 7%'	Immediately after flower picking
3	MB + 2, 4-D_1 + NAA_2 + K_1 + CM 10% + Sucrose 7%	The picked flowering branches put in room at normal temperature for 24 hours for moisture retaining and then transferred to refrigerator at 8-10°C for the same purpose for another 24 hours

* Micro elements doubled ; K = Kinetin ; CM = coconut milk.

** Except micro elements and auxins which were replaced by those in H medium, in all substances used were the same as in MS medium.

Throughout the culture period, the samples of anthers in culture were taken at 8 phases (*i.e.* 4th, 9th, 14th, 19th, 24th, 29th, 39th, and 49th day after inoculation) and fixed, embeded in paraffin before subjecting to continuous sectioning of the whole anther (each slice with a thickness of 10 – 12 μ) and staining with iron haematoxylin. Two anthers in culture were taken from each treatment at all phases for histological observations under microscope.

Studies with microscope were made on the cytology of calli, embryoids, root tips and leaves of plantlets. Pretreated with p-dichlorobenzene, the materials were fixed in Carnoy's fluid before staining with iron haematoxylin and subjected to squashing.

RESULTS

Generation of somatic callus

Within 2 – 3 days after inoculation, the anthers in culture changed from yellowish white to brown, while its volume contracted a little bit. Their periphery turned white or light yellow while their central parts remained the same colour 5 – 7 days after inoculation. Twenty days or so, pale yellow callus visible to the naked eyes appeared. Generally speaking, the induction rate was as high as 80 – 90% or even 100% in some instances. Observations on sections from continuous slicing of the whole anthers cultured for 4 days revealed the commencement of cell division at the cut end adjoining to the staminal column of a few cultures. Cell proliferation was observed at the apices and septa of the anthers 9 days after inoculation. These parts like the cut end, contained some parenchymatous cells of strong meristic capacity (Plate I, Figs. 1 – 3). At 19th day after inoculation, some large callus clumps emerged, the most active parts of division being the apex and cut end of the anther. Some part of the callus made their way into the pollen sacs, filling the entire empty space and pushing the abortive pollen grains aside. The differentciation of conducting tissue was seen at the central part of the callus at this stage. However, some anthers in culture were found callusing somewhat later (Plate I, Fig. 4).

Twenty-nine days after inoculation witnessed the rapid growth of callus into a size of 2mm with more conductive tissues, while the earlier-produced calli showed senescence and died. The latter case even could be observed from the segments from continuous sectioning of the anthers in culture for 25 days. It was not until the 39th day that a wide range of the calli perished, which was characterized by the increasing depth of its colour, from yellow to dark yellow till brown spots appeared.

The pollen granules in the pollen sacs took another way. Before culturing, 80% of the pollen grains were viable, but 97% of them disorganized 4 days after inoculation. Only four among the 12079 pollen grains observed showed 1–2 divisions before their death. It was also reported in the Annual Report of RRIM (1978) that the staminal column on a filter paper bridge over liquid medium could survive for 11 days.

Development of embryoids

The embryoids, composed of regularly-arranged cells with large nucleus, thick cytoplasm and dense stains, were noticed on the surface of the calli in all the three treatments (Plate I, Fig. 5) as early as 19 days after culturing. The embryoids then increased their sizes and quantity continuously. Some embryoids had a size of 0.4 mm at 39th day and the number of embryoids further went up (an average of 5 – 13 embryoids from each anther). But during the period between 39th – 49th days, an interesting phenomenon was noticed. The calli were found quickly aging, some even browned and died off, while profuse embryoids appeared, doubling and redoubling in number (Plate I, Fig. 6, Plate II – Fig 7, Table 2). In some cases, ten embryoids were visible on a single section. Upto the 49th day, the earlier produced embryoids started their differentiation of cotyledon (Plate II, Fig. 8). It is thus advisable to transfer the callus somewhat later rather than much earlier generally between 45th – 55th days (Wang Zeyun *et al*, 1980 ; Ceng Min *et al*, 1981 ; Huang Degui *et al*, 1982). The specific time for transferring should be dependent on the exact medium used, culturing conditions and the varieties adopted. In the case of higher induction frequency and good growth of callus, which would give rise to the rapid filling of the test tubes followed by earlier senescing, transferring should be carried out ahead of this schedule ; and vice versa.

Table 2. *Embryoid production at different phases*

Code number	Anthers for callus observation	No. of embryoids	
		39th day	49th day
1	2	26	70
2	2	10	26
3	2	12	31

The embryoids were only detected to have developed from the superficial layer instead of the inner part of the callus (Plate I, Figs. 5, 6, Plate II, Figs. 7, 8).

It can be seen from the above that the embryoids from the somatic cells of *Hevea* anthers originate in the cells in the surface layer of callus derived from some parenchymatous cells, due to the resumption of their meristic ability, located at the cut end, apex, septum and wall of the anther in culture. But this is not always the case, for we also have noticed that some embryoids did not come out from the well established calli but directly from the parenchyma cells at the onset of its division.

Timely transferring of the callus on to the second medium containing hormones at a reduced level generally encouraged the advent of pale embryoids visible to the naked eye, 7 days later. In some cases such embryoids appeared even within 7 days and took up half of the total production. However, a few embryoids showed themselves still earlier *i.e.* before the transferring of the callus.

After making their appearance, the majority of the embryoids ceased to develop any further. In 1977, the inoculation of 21286 anthers from Haiken 2 only contributed a yield of 15864 embryoids, the average being 0·7 embryoid per anther with 2·5 embryoids per anther in the peak-yield treatment. Nevertheless, our observation on the slices revealed the quantity of the mini embryoids invisible to the naked eye was much larger than this value. Moreover, among the embryoids visible to the naked eye, most of them remained at the globular and heart-shaped stages, very few could reach their maturity, *i.e.* the cotyledonous and trumpet-shaped stages (Plate II, Figs. 9, 10, 12, 14). This explains the underlying cause of low induction rate of plantlets.

Counting of chromosomes in calluses, embryoids and plantlets

Squashes of calli of different ages were prepared for observation. Among the 702 countable plates in division phase, 258 had 28 – 36 chromosomes (95·6%), 27 had 12 chromosomes (4·4%) and none contained 18 chromosomes. The embryoids and plantlets (young leaves or root tips) studied, shared the same pattern with callus in terms of chromosome number, indicating further that they all originated from somatic cells.

Table 3. *Chromosome number of calli, embryoids and plantlets under microscope*

Material	Quantity	No. of division phase					
		Chromosome number					
		18	19–26	27	28–36	>37	Total
Calli	25	0	0	12	258	0	270
Embryoids	50	2	5	3	454	13	477
Complete plantlets	9	4	0	9	146	0	159
Total	64	6	5	24	858	13	906

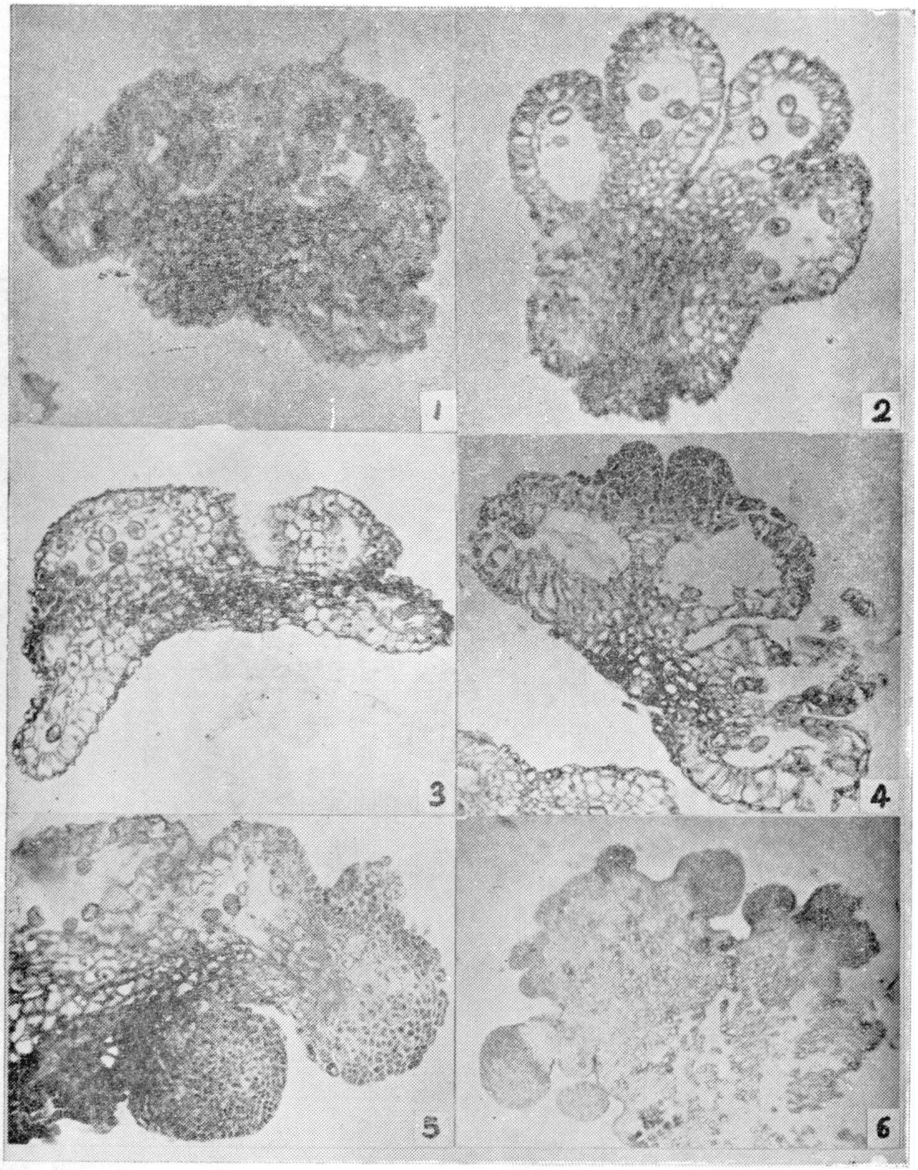


Plate I, Figs. 1 - 6. Embryogenesis and origin of *Hevea* anther plantlets.

1. **Anther at inoculation ;**
2. **Somatic cell division at cut end adjoining staminal column; most of pollen grain having been disintegrated (at 9th day) ;**
3. **Somatic cell division at apex (left) of anther ;**
4. **Somatic cell division at apex of anther (at 24th day) ;**
5. **Embryoids initiation from somatic callus (at 19th day) ;**
6. **Embryoids formation on somatic callus (at 49th day) ;**

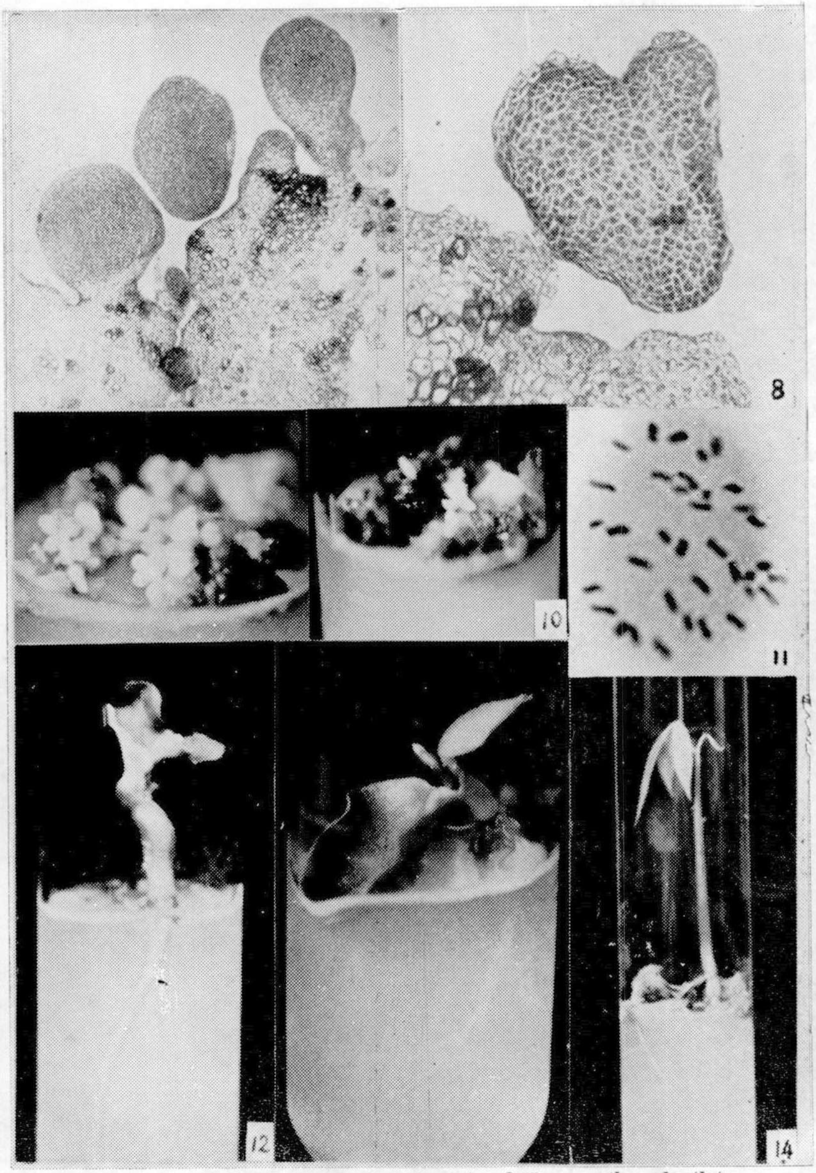


Plate II, Figs. 7 - 14. Embryogenesis and origin of *Hevea* anther plantlets.

7. Embryoids on somatic callus (at 49th day) ;

8. Onset of differentiation of cotyledon (at 49th day) ;

9 - 10. Embryoids at different developmental stages ;

11. Chromosome number of embryoids, 2n = 36 ;

12. Embryoid with tap and lateral roots ;

13. Embryoid with stem, tap root and lateral roots ;

14. Complete plantlet.

Phenotypical features of anther plantlets

Of the 38 anther plants stemming from Haiken 1, Haiken 2 (clonal progenies of elite single mother plant, F_1 hybrid, aged 3·5 – 5 years), except one showing abnormal growth, 37 share the same morphological characters with their mother clones, suggesting that no segregation occurs between individuals. In comparison with corresponding buddings, the anther plants grow faster, in that some of them have attained a girth of 50 cm, at 50 cm from the ground, 5 years after transplanting to the field from tubes.

Influence of low temperature and NAA on anther culture

Before inoculation, the inflorescences were kept at 8 – 10°C for 24 hours to serve the purpose of moisture maintaining, which led to higher induction rate of embryoids. But it was suspected that the low temperature pretreatment and no NAA addition to the medium might have some effects on the origin of the anther plants. To answer the question, three treatments (No. 1, 2 and 3) were laid out. Histological and cytological studies demonstrated that there was no difference in the origin of calli, embryoids and plantlets among the treatments, *i.e.* they were all derived from somatic cells.

DISCUSSION

The embryoids of different plant species have great variations in the development into plantlets. For example, the embryoids of such crops as sugar cane (*Saccharum officinarum*) and tobacco (*Nicotiana tabacum*) are highly responsive to the induction of further development into plantlets while those of the purgin croton (*Croton tiglium*) and castor (*Ricinus communis*) in the Euphorbiaceae family showed little response to the induction of growing into plantlets. *Hevea brasiliensis*, a species in the Euphorbiaceae family, falls into the latter type. A few Rubber Research Institutes have undertaken *Hevea* tissue culture for years and obtained embryoids years ago. But no report from them is available up to now on the success of induction and transplanting of plantlets from the embryoids. Some *Hevea* clones, such as Haiken 2, could proffer a 74% of induction rate of embryoids. In one single flowering season, several dozens of thousands of embryoids could be achieved from culture, and even more such embryoids could be detected with the microscope. But unfortunately only less than 1% of them could develop into plantlets, most of which stayed at the globular or primordial stages. These facts proved that the special conditions for embryoid initiation and those for the further development of generated embryoids into plantlets, are not the same, and that there is much room for improvement of plantlet induction frequency. Once the essential requirements for the further development of embryoids are satisfied, the induction rate of plantlets could be enhanced to a considerable extent. Therefore, it is of paramount importance to gain a good insight into the necessary conditions for the generation, especially for the further development of embryoids so as to lift up the efficiency of anther culture and enable it to be put into production practice.

During the period between 39 – 49 days after inoculation, copious calli aged, then browned and eventually died off, whilst profuse embryoids cropped out in a doubling way. It seemed that the senescence of the calli had something to do with the initiation of embryoids. Probably the calli released certain organic substances in the course of their senescence which provoked the origination of the embryoids. Wilson *et al* (1975) demonstrated that the extension of the culture duration of **Hevea** in suspension culture to 3 – 6 months imparted embryoids without any subculture. Analysis indicated that the "aged" cultures liberated a variety of amino acids (Wilson and Street, 1975).

Both China and Malaysia have got successes in the induction of anther plantlets through anther culture *in vitro*. The origin of the plantlets has been suggested from two sources, *i.e.* either from somatic cells or pollen cells. The reports available so far on the chromosomes of the anther plants showed great variations in chromosome number, especially that of root type and young leaves. The complex variations of chromosome number lies in the fact that some chromosome sets exhibited the ploidy of 9, *e.g.* $x = 9$, $2x$ (haploid) $= 18$, $3x = 27$, $4x$ (diploid) $= 36$, $5x = 45$, and some displayed the aneuploidy changes. This indicates that the loss or the addition of chromosomes could occur in the process of culture. This phenomenon has also been observed in the culture of other crop species. Tram Than Van (1977) obtained hypohaploid tobacco plantlets by way of rotation culture of its anther and other materials. He found that each rotation culture of the anthers led to the decrease of chromosome number of the regenerated plants. Under the conditions of complex variations of chromosome number, although it is still a basis for identifying the origin of the plantlets, histological studies could provide more important and direct evidences for the purpose.

Hevea, a cross-pollinated plant, is highly heterozygous. The materials used for anther culture are all clonal offspring of F_1 single plants. Provided that the plants from anther culture are of somatic cell origin, then no segregation would occur between individuals, and their morphological characters should be entirely the same with or principally identical to their donors and they would grow rapidly. But if they are derived from pollen, the situation would be essentially different. It thus follows that the phenotypical features for the anther plants offer another basis for the assay of the genesis of the plants.

REFERENCES

ANON, (1982). *In vitro* microcutting of ***Hevea brasiliensis*** young plants. ***5th International Congress IAPTC.***

Annual Report of the Rubber Research Institute of Malaysia, 1971 – 1979.

CARRON, M. P. AND ENJALRIC, F. (1982). Studies on vegetative micropropagation of ***Hevea brasiliensis*** by somatic embryogenesis and ***in vitro*** microcutting. ***5th International Congress IAPTC.***

CENG MIN, *et al* (1981). Studies on ploidy of chromosomes of ***Hevea*** anther in culture. *Genetic Journal,* 8 (2), 169 – 174.

GHANDIMATHI, H. AND PARANJOTHY, K. (1975). Anther culture-attempts at induction of haploidy in *Hevea* and other plants. ***Proceedings of the National Plant Tissue Culture Symposium.*** (1979), 32 - 35.

HUANG DEGUI, *et al* (1982). Anther culture of ***Hevea. Fujian Tropical Crops Science and Technology***, 1982 (2), 1 – 11.

JOHRI, B. M. (1971). Chinese translations of plant physio-biochemistry. (2), *Science Press*, 1976, 154 - 162.

PLANT INSTITUTE, SCIENCE ACADEMY OF CHINA (1973). Compilation of haploid breeding (2). *Science Press*. 26 - 38.

TRAN THANH VAN, K. (1977). *Selective Translations of Plant Tissue and Cell Culture Symposium* 27 - 50.

WANG ZEYUN, *et al* (1980). Studies on induction of *Hevea brasiliensis* from anther culture. *Journal of Tropical Crops*. **1** (1), 16 - 26.

WANG ZEYUN, *et al* (1982). Inheritance of some characters of somatic anther plants of *Hevea Tropical Crops Research*, 1982 (3), 14 - 17. (in Chinese)

WILSON, H. M. AND STREET, H. E. (1975). The growth, anatomy and morphogenetic potential of callus and cell suspension cultures of *Hevea brasiliensis*. *Ann. Bot*. 39, 671 - 682.

ZHENG JUSU (1979). Genesis of embryoids in culture of somatic cells of sugarcane. *Journal of Plant Physiology*. **5**, 411 - 416.

DISCUSSION

Q — MAJEED, RRI Indonesia : Tell us the rooting system of the embryo plantlets in tissue culture, can the root system be similar to the seedlings or cuttings.

A — CHEN CHUANQIN, China : Root system is quite similar to the seedlings.

Q — SIVAPALAN, TRI : Is it correct to say that you have tissue cultured rubber trees that are in tapping.

A — CHEN CHUANQIN, China : We have brought plantlets into tapping and the yield is higher than the clonal plants.

Q — SIVAPALAN, TRI : How many trees.

A — CHEN CHUANQIN : At present we have obtained 80 plantlets but only 7 trees have come under tapping.

Q — SIVAPALAN : How long after planting were they tapped.

A — CHEN CHUANQIN : About 5 years.

Q — INDRANI SIVASUBRAMANIAM, TRI : Are these anther plantlets haploid or diploid.

A — CHEN CHUANQIN : They are diploid.

Q — INDRANI SIVASUBRAMANIAM : Wouldn't they resemble the parent plant.

A — CHEN CHUANQIN : They come from somatic cells. They are diploid.

Q — INDRANI SIVASUBRAMANIAM : Have you ever been able to get plantlets from pollen grain.

A — CHEN CHUANQIN : No

NURSERY EVALUATION OF CLONAL SEEDLINGS OF *HEVEA BRASILIENSIS* MUELL. ARG.

By

C. K. Saraswathy Amma, V. C. Markose, Joseph G. Marattukalam and A. O. N. Panikkar

(Rubber Research Institute, India)

ABSTRACT

Open pollinated clonal seeds from five modern clones of Hevea brasiliensis *were collected, germinated and the seedlings raised in the nursery in a randomized block design. The growth characteristics were studied in the nursery stage. The seedlings were budgrafted with a common scion donor and the budtake on these seedlings was observed. The results revealed that there is significant variation with regard to diameter of seedlings of different clones at the buddable stage. The heritability for this trait was 62 per cent. The budding success also showed clonal variation. The success was low for stocks genetically related to the scion, indicating that there is a certain level of genetic influence on successful budtake.*

INTRODUCTION

During the initial stages of rubber cultivation the rubber tree, *Hevea brasiliensis* Muell. Arg., was propagated exclusively by seeds. After the perfection of the budgrafting technique, by Van Helten in 1917, the vegetative method of propagation became popular. Seedlings, however, are indispensable as stock plants for budgrafting. In India root stocks are usually raised from assorted seeds collected from commercial fields. As the budgrafting method became the accepted method of propagation, the relationship between stock and scion assumes importance. Stock-scion interaction had been established in fruit crops like apple and pear (Hartmann and Kester, 1968). Some attempts have been made to identify *Hevea* clones whose seedlings are comparatively better stocks for certain scions. There is a good range of modern cultivars comprising of secondary and tertiary clones. It may be expected that the seedlings from different clones may show variation in growth. Hence, evaluation of the seedling population from various clones is of importance. Work on this aspect has already been initiated in Sri Lanka, Indonesia and Malaysia (Fernando and De Silva, 1971 ; Bahtiar and Syafar, 1981 ; Ng Al Peng, 1983). The present study was taken up with a view to study the early performance of the seedlings of a few clones as stock plants.

MATERIALS AND METHODS

Open pollinated seeds of five *Hevea* clones, RRII 105, RRII 118, RRII 203, RRIM 600 and GT 1 were included in the study. The origin of these clones is given in Table 1. The seeds were germinated in the normal manner. 120 germinated seeds from each clone were planted in the nursery in a randomized block design with three replications of 40 seedlings per plot. The planting was done in four rows of ten points each and the data were collected from the sixteen inner plants. Measurements of height were taken at the 3rd, 6th and 10th month of planting. At 10 months age, the diameter just above the collar region and number of leaves of the seedlings were also recorded. These seedlings were budded with RRII 105 as the scion and the budding success was ascertained.

Table 1. *Materials*

Clone	Parentage	Origin
RRII 105	Tjir 1 × Gl 1	India
RRII 118	Mil 3/2 × Hil 28	India
RRII 203	PB 86 × Mil 3/2	India
RRIM 600	Tjir 1 × PB 86	Malaysia
GT 1	Primary clone	Indonesia

RESULTS AND DISCUSSION

The mean diameter, height and number of leaves of the seedlings belonging to different clones showed variation at 10 months of age (Table 2). Seedlings of RRII 203 recorded the maximum height followed by those of RRII 118 and GT 1. With regard to diameter, the seedlings of GT 1 showed highest vigour followed by those from RRII 118 and RRII 203. GT 1 seedlings also showed the highest number of leaves. The data were subjected to statistical analysis and significant variation between clones was recorded only in the case of diameter (Table 2). Seedlings of GT 1, RRII 118, and RRII 203 showed significant superiority in terms of diameter compared to the seedlings from the other clones. The components of variance for diameter are given in Table 3. Heritability for diameter was found to be high. High genotypic variance and high heritability indicate the involvement of additive genetic action for this character.

Table 2. *Mean height and diameter of seedlings at 10 months*

Clone	Height (cm)	Diameter (mm)	Total number of leaves
RRII 105	142·2	13·83	22·6
RRII 118	162·7	16·54	29·9
RRII 203	163·2	15·11	27·6
RRIM 600	142·0	13·52	28·8
GT 1	158·8	16·63	31·1
S. Em	6·94	0·61	2·31
C.D	N.S.	1·99	N. S.
CV %	7·82	6·94	14·29

Table 3. *Components of variance for diameter*

Phenotypic coefficient of variance	—	11·00
Genotypic coefficient of variance	—	9·914
Heritability (h^2)	—	0·6169
Genetic advance at 5% selection interval	—	2·14

The seedlings of clones RRII 118, GT 1 and RRII 203 showed high budding success (75 to 76%), while seedlings of RRII 105 and RRIM 600 gave only 49 and 56 percent, respectively. The percentage of budding success is depicted in Table 4. The low budding success obtained on seedlings of clones RRII 105 and RRIM 600 may be due to the genetic relationship of the scion. In this context it may also be recalled that Tjir 1 is a common parent for both the clones. The present observations thus indicate low budding success where the stock and scion are genetically related.

Table 4. *Percentage of budding success*

Clone	Total number budded	Success	Percentage
RRII 105	41	20	49
RRII 118	42	32	76
RRII 203	40	30	75
RRIM 600	32	18	56
GT 1	42	32	76

Significant difference in vigour has been already noticed in certain clonal seedling families (Bhaskaran Nair, 1966 ; Anonymous, 1966). Vigorous seedlings can make available a greater number of stock plants for budding. Variation of yield and girth within clones has been more often attributed to local environmental factors and also to different genotypes of the rootstock (Gordon Haskell, 1961). The rhythm of growth is genetically determined and is related to vigour. The diameter of the seedling can be used as a parameter for nursery selection (Jayasekera and Senanayake, 1971). Results of the experiments conducted in Malaysia have shown that there is rootstock effect on scion growth and yield (Ng Al Peng, 1983). As the early growth of the scion will depend on the vigour of the stock, it is always desirable to use more vigorous seedlings as stock plants. The study revealed that seedlings belonging to different clones show variation in growth vigour. In addition budtake also appeared to be influenced by genetic relations to some extent. Selection of seeds for raising stock seedlings is therefore important. The genetic influence of stock-scion interaction at different phases of growth also deserves detailed study.

ACKNOWLEDGEMENTS

The authors are grateful to Dr M. R. Sethuraj, Director, Rubber Research Institute of India for providing necessary facilities for this study. They also thank G. Subbarayalu, Statistician for the statistical analysis.

REFERENCES

ANONYMOUS, (1966). RRIM clonal seedling trials. *Plr's Bull. Rubb. Res. Inst. Malaya* No. **82** : 10 - 15.

BAHTIAR, S. A. AND SYAFAR, G. (1981). Influence of rootstock and trunk on girth increment in *Hevea* rubber. *Bull. BPP. Medan*, **12**, 129 - 136.

BHASKARAN NAIR, V. K. (1966). Growth performance of clonal seedling families under test on estates. *Rubb. Bd. Bull.* **8**, 20 - 25.

FERNANDO, D. M. AND DE SILVA, M. S. C. (1971). A new basis for the selection of *Hevea* seedlings. *Q. Jl. Rubb. Res. Inst. Ceylon.* **48**, 19 - 30.

GORDON HASKELL (1961). Seedling morphology in applied genetics and plant breeding. *The Bot. Review*, **27**, 382 — 420.

HARTMANN, H. T. AND KESTER, D. E. (1968). *Plant propagation principles and practices.* P. 561, Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

JAYASEKERA, N. E. M. AND SENANAYAKE, Y. D. A. (1971). The study of growth parameter in a population of nursery rootstock seedlings of *Hevea brasiliensis* Cv Tjir 1. *Q. Jl. Rubb. Res. Inst. Ceylon*, **48**, 66 - 81.

NG, AL PENG, (1983). Performance of rootstocks. *Plr's Bull. Rubb. Res. Inst. Malaysia* No. **175**, 56 - 63.

Session 2. BREEDING AND SELECTION

RRIC 100 SERIES CLONES—POTENTIAL AND POLICY

By

D. M. FERNANDO
(*Rubber Research Institute, Sri Lanka*)

ABSTRACT

The yields and other characters of the RRIC 100 series clones observed in experimental and commercial fields are described. Resistance to Colletotrichum, Oidium *and, in later selections, resistance to South American leaf blight, have been noted in these clones. Greater vigour permitting earlier opening has been confirmed. An effective comparison has been made with the popular Malaysian clone RRIM 600. The planting of SALB resistant clones, on experimental plots on large estates is advised in order to protect the industry.*

Although RRIC 100 has been distributed as nucleus budwood to estates from 1971, it is only in the 1980's that an appreciable replacement of the popular clone PB 86 has occurred in rubber plantings. The yields of PB 86 do not differ greatly from earlier selections such as Mil 3/2 and Wagga 6278 as shown in Table 1.

Table 1. *Commercial cumulative yields (kg/yr)*

Clone	3 years	6 years	9 years
PB 86	2033	5484	9799
Mil 3/2	1450	4459	9341
Wagga 6278	1242	5740	9658

However, on the basis of low immature vigour and susceptibility to *Colletotrichum* leaf disease, which can further extend the period of immaturity, PB 86 was dropped from large scale recommendations in Malaysia in 1958. In Sri Lanka wind damage in the second and third years of tapping, reducing stand by 30% to 50%, brought in substitute clones such as RRIM 600 and RRIM 623. One such area damaged in 1966 was planted in 1967 with Gt 1 and a large scale trial of RRIC 100, RRIC 111, and other selections.

From a few areas in commercial planting we have been able to obtain total annual yields (Table 2) and at least one large State Sector Corporation has moved for 100% planting of these new clones.

Table 2. *Commercial cumulative yields (kg/yr)*

Clone	3 years
RRIM 600	2065
RRIC 100	2721
RRIC 102	4005

Growth

The increase of immature vigour in the RRIC 100 series clones, reducing the period of immaturity is now confirmed in clone trials sited in Sri Lanka and in other countries which have participated in the 1974 Multilateral Clone Exchange.

From earlier clone trials planted, it has been possible to monitor the increase of girth after tapping over a period of years. A satisfactory increase of this parameter is essential to counteract trunk snap in high yielding clones and ensure sufficiently strong renewed bark. It has been found that RRIC 121, RRIC 102, RRIC 111, RRIC 104, and RRIC 110, have all shown a rate of over 2 cm increase of girth after tapping, which is slightly better than that shown by the control RRIM 623. This rate of increase has been maintained for over 10 years in small scale clone trials. There could be severe erosion in some fields due to replanting and a cultivar with substantial increase of girth after tapping will permit extension of the replanting cycle with yields increasing steadily with girth : in eroded fields this would permit a leaf mulch to build up.

Yields

Any level of significant difference between per tree per tapping yields is usually very difficult to obtain, unless perhaps associated with undesirable characters such as a tendency to dryness. In one experiment with seven clones and the control clone RRIC 45 spread throughout the area, a significant difference has been shown by RRIC 100, RRIC 102 and RRIC 103 to a very marked extent (Table 3).

Table 3. *Comparison with control RRIC 45*

Clone	Yield (1983) 7th year of tapping
RRIC 100	**
RRIC 102	***
RRIC 103	***

** Significant at 1 % level on paired ' t ' test.
*** Significant at 0·1 % level on paired ' t ' test.

Yields of renewed bark from a large scale trial amount to 1300 kg/ha for RRIC 102 and 961 kg/ha for the control clone RRIM 623.

The thickness of renewed bark of RRIC 100, RRIC 102, RRIC 103, RRIC 104 and RRIC 110 was found to be within 1 mm of the virgin bark. The bark of those clones replicated in drier areas such as Moneragala was found to be thicker than that in the wet zone. The number of latex vessel rings was less by one in the renewed bark of all these clones, when compared to the virgin bark.

The favourable secondary characters of vigour after tapping and bark thickness indicate that there is sufficient partition of assimilates to growth of the tree in order to balance the loss in latex and bark shavings.

RRIM 623 was planted as the control clone in large scale trial as vigour was comparable. However, one of the leading commercial clones on yield is RRIM 600 and a comparison of commercial yields of RRIM 600 and experimental yields from over 900 trees of RRIC 100, RRIC 102, and RRIC 103 are shown in Table 4.

Table 4. *Comparative cumulative yields (kg/ha)*

Clone	3 years	6 years	9 years
RRIM 600	2065	6761	13 100
RRIC 100	3316	10529	—
RRIC 102	3644	8960	—
RRIC 103	3367	9159	15 688

In order to further clarify the comparison of RRIC 103 with RRIM 600 a clone trial with several randomized 100 tree plots of a number of clones was monitored in the sixth year of tapping on all tapping days. As seen in Table 5 similar yields were accompanied by a significantly better girth of RRIC 103.

Table 5. *Comparison of RRIM 600 & RRIC 103*

Clone	Sixth year of tapping	
	g/t/t	girth (cm)
RRIM 600	23·0	53·6
RRIC 103	23·1	58·4*

* Significant at 5% level

South American leaf blight (SALB)

A number of clones resistant to SALB were imported in 1958 from Costa Rica via quarantine in Florida and inspection and treatment at Kew. A few of the budgrafts were ring barked in 1960 in order to induce flowering and hand pollinations were made in 1961. On the basis of vigour and resistance to *Oidium* and *Colletotrichum* leaf diseases, a few selections were sent to the RRIM Station at Trinidad for screening against SALB.

RRIC 117, RRIC 121, and RRIC 130 have emerged as high yielding material showing resistance ; of these clones RRIC 121 has exhibited the most favourable levels of yield and growth. Although we have had no large scale trials of this clone in tapping in order to recommend large scale planting, there has been a steady demand for replanting to the limit of available budwood from both the state and private sector. However, in view of the speciation of *Microcyclus ulei* into many races, now seven, it is very advisable to have a number of SALB resistant clones in planting and state estates have included RRIC 117 and RRIC 130.

In continuing breeding programmes it may be advisable to repeat some of the earlier crosses as RRIC 121 has been selected from only four progeny of PB 28/59 x IAN 873 and RRIC 132 from only 26 seedlings of the cross IAN 717 x RRIC 117. A comparative freedom from infection was observed in a nursery population of PB 28/59 at El Palmar, Vera Cruz, (Fig. 1), in contrast to appreciable infestation on RRIC 101 (Fig. 2).

Brazil has been successful in combining the SALB resistant everflowing dwarf *H. camargoana* with clones such as IAN 873 to give well-grown resistant plants which are shown (Fig. 3) to thrive even on exposure to the virulent *M. ulei* races at Manaus (Goncalves *et al*, 1980).

An interesting facet of susceptibility to *M. ulei* was noted when IAN 710 plants were ring barked at Vera Cruz in order to induce flowering. A very heavy infestation of *M. ulei* resulting in etiolation, leaf fall and die-back followed the ring barking.

DISCUSSION

Simmonds (1969) pointed out that a multiplicity of favourable characters either demanded large populations or caused a weakened selection for individual characters. However, even selected seedling populations of *Hevea* cannot reach the yield peaks achieved by single clones selected from a family. Therefore, a number of clones varying in degrees of individual favourable secondary characters and all possessing above average yields appears to be the next best alternative in planting. Therefore, a 30 percent of SALB resistant clones RRIC 117, RRIC 121, RRIC 130, RRIC 132 with RRIC 121 predominating, could possibly counter the speciation of *M. ulei* if it does happen to arrive in Sri Lanka. RRIC 100, RRIC 102, RRIC 103, RRIC 110 could comprise the remaining 70% with RRIC 102 and RRIC 103 above 300 m elevation.

Harvesting from these clones presents problems of collection and transport ; increase of collecting centres and assistance in collection have been adopted in some estates.

Ang and Shepherd (1979) have drawn attention to the increased potential for use as timber if very vigorous clones are planted. At present in Sri Lanka much rubber wood is used for fuel. More research on density of planting of these new clones may furnish dual purpose plantings with early felling of inter-rows as these newer clones exceed most forest trees in rate of growth.

Wycherley (1969) has remarked that yield trends from renewed bark can be predicted reasonably well from the trend on virgin bark, the quality of the renewal and in particular the growth of the tree (girth increment) during tapping. RRIC 102, RRIC 103, and RRIC 121 show very favourable trends with respect to renewed bark. Some areas due for replanting show very difficult terrain and it would be very advisable in such areas to replant with clones which are strong on renewed bark yields, thereby extending the period of exploitation and allowing leaf mulch to build up.

De Jonge (1969) has drawn attention to yield fluctuation on deep and shallow tapping; this would provide flexibility during periods of high prices. In RRIC 100 series, estates have noted marked differences on yields depending on the depth of tapping.

Fig. 1. Nursery plants of PB 28/59 at El Palmar Station, Vera Cruz, Mexico.

Fig. 2. Nursery plants of RRIC 101 and 102 at El Palmar.

Fig. 3. Well grown SALB resistant plant at Manaus.

Therefore, going into new planting materials calls for more management and control in order to reap the benefits that would accrue from more vigorous, higher yielding clones showing other favourable secondary characters as well.

Baptiste (1961) drew attention to the necessity of breeding for higher yield and disease resistance in *Hevea*, especially resistance to South American leaf blight, rated as one of the most destructive tree diseases.

Barlow and Ng (1966) drew attention to the importance of opening trees earlier in order to increase economic viability of the rubber industry. Ng *et al* (1969) found marked correlations between average yield per ha on estates and the profit margin.

ACKNOWLEDGEMENTS

The assistance of the staff of the Genetics and Plant Breeding Department of the RRISL is gratefully acknowledged. The help of Sr Paulo de Goncalves and Dr N. E. M. Jayasekera in the more recent studies is also acknowledged. Dr O. S. Peries is also thanked for his encouragement and support.

REFERENCES

ANG, B. B. AND SHEPHERD, K. (1979). Promising new Prang Besar clones. *Proc. Rubb. Res. Inst. Malaya. Pltrs. Conf. Kuala Lumpur*. 219.

BAPTISTE, E. D. C. (1961). Breeding for high yield and disease resistance in *Hevea. Proc. Nat. Rubb. Conf. Kuala Lumpur*. **1960**, 430.

BARLOW, C. AND NG, C. S. (1966). Budgeting on the merits of shorter immature period. *Pltrs' Bull. Rubb. Res. Inst. Malaya*, **87**, 216.

DE JONGE, P. (1969). Influence of depth of tapping on growth & yield of *Hevea brasiliensis. J. Rubb. Res. Inst. Malaya*, **21**, 348.

GONCALVES, P. DE S. FERNANDO, D. M. AND ROSSETTI, A. G. (1981). A nursery progeny test of SALB resistant hybrids of interspecific crosses of *Hevea. J. Rubb. Res. Inst. Sri Lanka*. **57**, 13 — 21, 1980.

NG. C. S., BARLOW, C. AND CHAN, C. K. (1969). Factors effecting the profitability of rubber production on west Malaysia estates. *J. Rubb. Res. Inst. Malaya*, **21**. 654.

SIMMONDS, N. W. (1969). Genetical bases of plant breeding. *J. Rubb. Res. Inst. Malaya*, **21**, 1.

WYCHERLEY, P. R. (1969). Breeding of *Hevea*. *J. Rubb. Res. Inst. Malaya*, **21**, 38.

DISCUSSION

Q — J. DE O. CEZAR, Brazil : About *Hevea camargoana*. Are you using it or not ?

A — D. M. FERNANDO, Sri Lanka : No. we have *Hevea nitida*, variety *toxidendroides*. *Hevea, camargoana* is from Sr Goncalves work in Brazil.

A REVIEW OF STUDIES ON GENOTYPE-ENVIRONMENT INTERACTIONS IN *HEVEA*

By

N. E. M. JAYASEKERA
(*Rubber Research Institute, Sri Lanka*)

ABSTRACT

Studies on genotype-environment interactions in Hevea *were started in 1975. Ten clones and eight experimental sites were used in these studies. The analysis of data on five characters showed significant genotype-environment interactions, Three characters showed non-linear interactions. Therefore, taking the variance as the index of stability, a method has been suggested to select stable clones with above or below average performance depending on the character under consideration. The analysis of the other two characters indicated that the genotype-environment interactions are mainly linear. For both characters regression lines of the 10 clones were found to intersect each other more or less at the same point as indicated by significant concurrence. Therefore, the differences in performance between clones become more evident with the improvement of the environment.*

INTRODUCTION

The existence of interactions between genotypes and environments has been recognized for a long time. In the presence of genotype-environment interactions the relative performance of genotypes may vary when grown in different environments. This can give rise to fluctuations in performance of genotypes over different environments. Allard and Bradshaw (1964) have discussed the implications of genotype-environment interactions in plant breeding.

Plant breeders now try to select genotypes stable to environmental variation. To achieve this objective more information on genotype-environment interactions with particular reference to stability performance under different agro-climatic conditions is necessary. The need for such information has been stressed by Swaminathan (1975).

At the Rubber Research Institute of Sri Lanka, studies on genotype-environment interactions were started in 1975. In this paper an attempt is made to review the findings made from an experiment started in 1975 and discuss possible uses of these findings in selecting stable rubber clones.

MATERIALS AND METHODS

The experimental material, design and the five characters analysed, have been described in previous publications (Jayasekera, Samaranayake and Karunasekera, 1977 ; Jayasekera, 1983 ; Jayasekera and Karunasekera, 1984).

RESULTS AND DISCUSSION

All five characters analysed, showed significant genotype-environment interactions (Table 1).

Table 1. *Results of the analyses of variance*

Item	1st height	2nd height	Survival rate	6th year girth	2nd year yield
1. Clones	***	***	***	***	***
2. Locations	***	***	***	***	***
3. Clones × Locations	*	*	*	*	***

Levels of significance

NS = Non Significant　　* = 1·0 — 5·0%

** = 1·0 — 0·1%　　*** = <0·1%

To study the nature of genotype-environment interaction component a joint regression analysis was performed on each character as suggested by Perkins and Jinks (1968).

According to the results of these analysis, the five characters fall into two groups. The survival rate and two height measurements showed non-linear genotype-environment interactions and therefore can be grouped together. On the other hand with respect to sixth year girth and second year test tapping yield interactions were mainly linear. To illustrate this point the results of the joint regression analysis for the first height measurement and second year test tapping yield are given in Table 2.

Table 2. *Joint regression analysis : mean squares and results of significance test (in paranthesis)*

Item	First height measurement	2nd year yield
Among slopes	214·33 (N.S.)	79·17 **
Residual (non-linear)	977·34	17·57

Level of significance same as for Table 1.

By considering the two characters as typical of the two groups, it is possible to discuss the nature of genotype-environment interaction among the 10 *Hevea* clones. For the first height measurement, the among slopes item is not significant and the mean square of the non-linear item is greater than the among slopes item. Therefore, it is evident that the differences between regression lines do not fully explain the genotype-environment interaction detected in this character.

The interactions with respect to second year test tapping yield are mainly linear as shown by the significant among slopes item (Table 2). In the case of sixth year, girth among slopes item just failed to be significant at 5% level. But a major part of the genotype-environment interaction of this character could still be explained by the differences between slopes among regression lines. For this character the among slopes mean square was twice (13·98) in magnitude, when compared with that of the non-linear component (6.71).

In the presence of non-linear genotype-environment interaction, regression coefficients cannot be used as a stability parameter. Under such conditions variances of clones over environments can be used as stability indicies (Jinks, Jayasekera and Boughy, 1977 ; Jayasekera, 1983 ; Hill 1975). Some workers have used the coefficient of variation as a stability index instead of using the variance directly (Funnah and Mak, 1980).

In addition to stability, mean performance (mean of each clone over all the environments) too, must be considered when selecting a clone. Depending on the character, one would like to select a clone having either an above average or below average performance.

With respect to height in *Hevea* a short clone is preferred to minimize wind damage. Therefore, the breeder would like to select a clone with below average height and above average stability. Jayasekera (1983) had suggested to use the scatter diagram (Fig. 1) obtained by plotting the mean performances and stability indicies of clones as an aid to joint selection for both criteria. In this method of selection mean stability and the mean height of the population have been used to divide the diagram into four quarters as indicated in Fig. 1. This helps to classify the ten clones into four groups with different levels of mean performances and stabilities. In the case of height, clones with below average heights and above average stabilities fall into the HL quarter of the scatter diagram.

The same selection procedure could be used for other characters which show non-linear genotype-environment interactions.

In the case of second year yield where genotype-environment interactions were found to be mainly linear, the among slopes item with 9 degrees of freedom was further partitioned into two components, concurrence and non-concurrence, with one degree of freedom and eight degrees of freedom respectively, as suggested by White, Lavender, Ching and Hinz (1981). Results are presented in Table 3.

Table 3. *Partitioning of among slopes item of yield*

Item	Degrees of freedom	Level of significance
Among slopes	9	**
Concurrence	1	***
Non-concurrence	8	N.S.

Level of significance same as for Table 1.

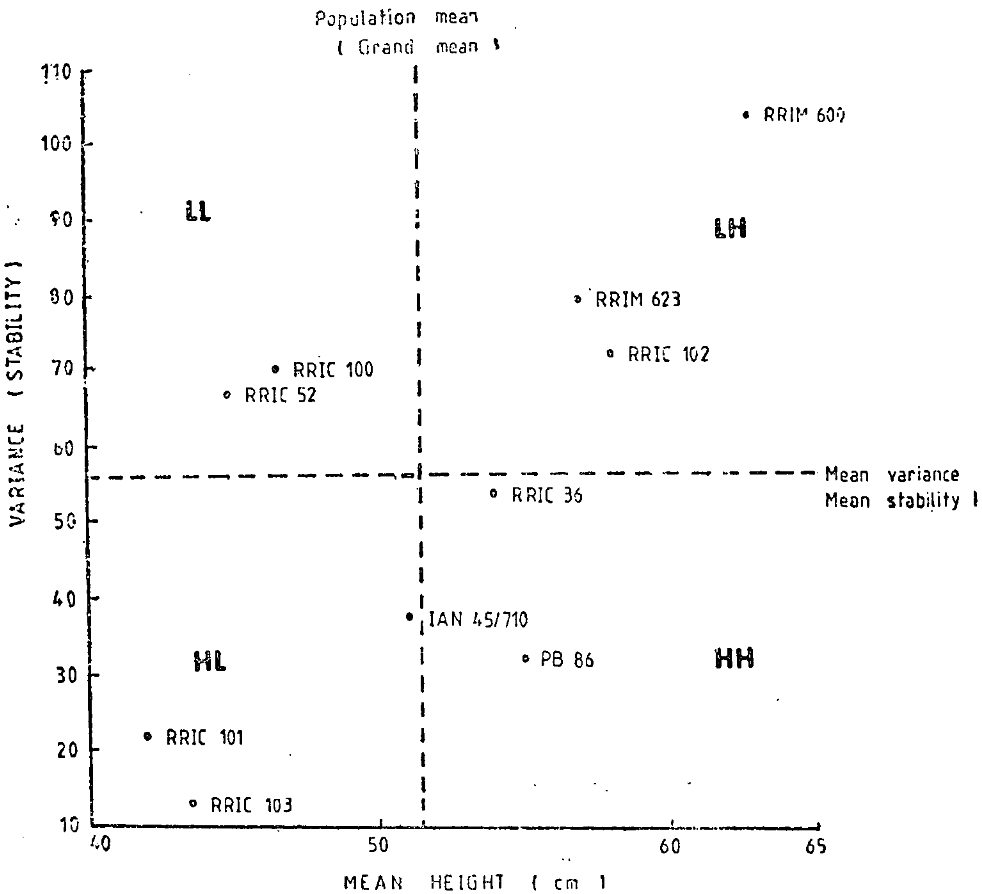


Fig 1. Mean height for each clone plotted against the variance over environments.

The significant concurrence and lack of non-concurrence as shown in Table 3, suggest that 10 regression lines, obtained by regressing clone mean in each environment on to the mean performance of all clones in that environment, have a common point of intersection, *i.e.* they cut each other more or less at the same point and fan apart from this point of intersection, this was found to be true for the 6th year girth also.

If the interaction is linear, regression coefficients can be used as stability indicies (Finlay and Wilkinson, 1963).

A highly significant positive correlation of 0·8899 was observed between regression coefficients of clones and their mean yields when averaged over environments. This indicates that high yielding clones respond to better environments by giving higher yields than the lower yielding clones. In other words as the environment improves the differences between high and low yielding clones become more evident.

In the case of 6th year girth, the correlation was positive though not significant.

In the presence of linear genotype-environment interactions, regression coefficients and mean performances have been used as selection criteria for selecting varieties or clones with different levels of stabilities and performances. But due to significant positive correlation between stability and mean performance, as found in yield, they cannot be used as independent selection criteria. In the presence of significant positive correlation, selection of clones for high mean performance will automatically select clones with high regression coefficients. With respect to second year test tapping yield regression, coefficients ranged from 0·4905 to 2·1010. According to Finlay and Wilkinson (1963) clones with regression coefficients significantly greater than 1.00 are specifically adapted to high yielding environments. They will give poor yields when grown under unfavourable conditions.

ACKNOWLEDGEMENT

I am grateful to the Editor, Silvae Genetica, for permitting me to reproduce Fig. 1 and some of the relevant materials from Silvae Genetica Vol. 32.

REFERENCES

ALLARD, R. W. AND BRADSHAW, A. D. (1964). Implication of genotype-environment interactions in applied plant breeding. *Crop. Sci.* **4**, 503 — 508.

FINLAY, K. W. AND WILKINSON, G. N. (1963). The analysis of adaptation in plant breeding programme. *Aust. J. Agric. Res.* **14**, 742 — 754.

FUNNAH, S. M. AND MAK, C. (1980). Yield stability studies on soya beans. *Expl. Agric.* **16**, 387 — 392.

JAYASEKERA, N. E. M., SAMARANAYAKE, P. AND KARUNASEKERA, K. B. (1977). Initial studies on the nature of genotype-environment interactions in some *Hevea* cultivars. *J. Rubb. Res. Inst. Sri Lanka*, **54**, 33 — 42.

JAYASEKERA, N. E. M. (1983). A basis of selecting *Hevea* clones stable to unpredictable agro-climatic variability. *Silvae Genetica* **32**, 181 — 184.

JAYASEKERA, N. E. M. AND KARUNASEKERA, K. B. (1984). Effect of environment on clonal performance with respect to early vigour and yield of *Hevea brasiliensis*. *Proceedings of Hevea exploitation and physiology meeting, I.R.C.A. — G.E.R.D.A.T., France.*

JINKS, J. L., JAYASEKERA, N. E. M. AND BOUGHY, HILLARY (1977). Joint selection for both extremes of mean performance and of sensitivity to a macro environmental variable. II. Single seed descent. *Heredity*, **39**, 345 — 355.

PERKINS, JEAN M. AND JINKS, J. L. (1968). Environmental and genotype-environmental variability. III. Multiple lines and crosses. *Heredity* **23**, 339 — 356.

SWAMINATHAN, M. S. (1975). Recent trends in plant breeding. *International Rubber Conference, Kuala Lumpur, Malaysia.*

WHITE, T. L., LAVENDER, D. P., CHING, K. K. AND HINZ, P. (1981). First year height growth of Southwestern Oregon Dougles-fir in three test environments. *Silvae Genetica*, **30**, 173 — 178.

DISCUSSION

Q — SHANMUGANATHAN, CRI : You said that there is no significant differences between vigorous and non-vigorous clones in their response to the improvement of the environment. Are you including the different climatic conditions ?

A — N.E.M. JAYASEKERA RRI., Sri Lanka : In the joint regression analysis, the among slopes item was not significant for girth. This indicates that the majority of the regression lines are more or less parallel. Therefore, this means that, in general, there was no marked differences between vigorous and non-vigorous clones in their response to the improvement of environment.

In this study the environmental differences are based on agro-climatic differences between different planting districts.

Q — SHANMUGANATHAN, CRI : Suppose the nature of genotype environment interaction varies in different sets of environments.

A — N.E.M. JAYASEKERA, RRI., Sri Lanka : Depending on the nature of the interaction we can select stable clones. If the interaction is linear, then regression coefficients can be used as stability indicies. If it is nonlinear variances of clones over environments can be used as stability indicies.

A GEO-ECOLOGICAL STUDY OF RUBBER TREE CULTIVATION AT HIGH ALTITUDE IN CHINA

By

JIANG, AILIANG

(Institute of Geography, Academia Sinica, Beijing)

ABSTRACT

It is customary to restrict rubber cultivation to an elevation below 500 meters but in China rubber has been profitably grown from 1000 to 1300 metres above sea level. Cold and sunshine both tend to damage rubber at high altitudes. The selection of the suitable planting material and analysis of the methods to overcome the environmental obstacles to growth and latex production are presented.

INTRODUCTION

The highest elevation at which rubber (*Hevea brasiliensis*) has ever been grown is at Nanjingli (1,310 m above sea level, 24° N, 98° E), Ruili Country, Yunnan Province, China. Six rubber trees which were planted at the Dehong Experimental Station of Tropical Crops in 1961, had survived for 20 years showing almost normal growth and satisfactory latex production. These trees were under a test planting project, while commercial rubber cultivation reached its highest elevation at 1·200 m above sea level (a.s.l.) in team no. 12 (23·5° N) of the Mengsa State Farm, Linchang Prefecture. At an elevation of 1,000 m or more, rubber cultivation takes place also to a greater extent in Xishuangbanna, Linchang and Simao Prefectures, Yunnan Province (Fig.1) where rubber trees are grown at an altitude of 1,060 m in Atu Village (22° N, Jinghong County (22° N, 101° E). Even in the Anning river valley, at an altitude of about 1,000 m, north of almost 26° N, rubber cultivation has been successfully carried out for more than 20 years. In contrast to these observations, rubber cultivation in Hainan Island, which is situated in the tropical zone of China, reaches to about 350 m only (in the northern part) and 500 m in the southern part.

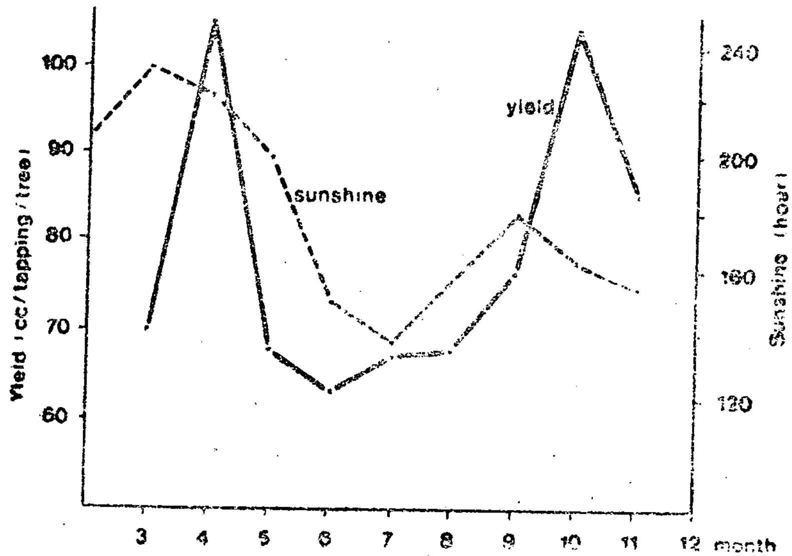


Fig. 1. Performance of sunshine and latex yield in Jinghong County.

Note : Data of latex production (PB 86) were provided by the Jinghong Tropical Crops Research Institute and sunshine data by the Jinghong Meteorological Station.

It can be seen that rubber grows at higher elevations in west and south-west Yunnan than in any other rubber planting area of China or any region of the world. According to the data available[1], in Sri Lanka, the highest elevation for commercial rubber planting reaches up to 500 m and for test planting however up to 900 m. The highest elevation at which rubber is grown in Malaysia and Indonesia is even lower. Although Sri Lanka is lying in a rather low latitude (6 – 10° N only), it still cannot grow rubber at such a high elevation as China does in Yunnan, at Ruili (24° N), Yingjiang (24° 45' N) and Jinghong (22° N). An attempt is being made on the basis of ecological habits, characteristics of the rubber tree and the specified geo-ecological environment in the south-west and the south of Yunnan Province and the south-west of Sichuan Province. This paper gives an account of the history of rubber cultivation at high altitude in Yunnan Province.

In 1904, Diao Yinsheng, a tribal headman in Yunnan Province, returned from Singapore with 8,000 rubber seedlings and planted them on the southern slopes of Fenghuang mountain (24°, 45° N, 98° E, 980 m a.s.l.) in Yingjiang Country, Dehong Prefecture in western Yunnan. However, about 2,000 plants only survived. However, by early 1950's only two trees still survived. Twenty years later, one of the two trees died of severe wind damage, according to a field survey by scientists from the Dehong Experimental Station in 1978. So far, only one tree has remained, 33·5 m in hight with a girth of 2·4 m at 150 cm above the ground. The girth recorded in the autumn of 1981 was 313 cm with a diameter of around 1 m. This rubber tree is now 80 years old, it is thus the oldest one in China. In contrast, rubber trees were first introduced to Jiayi Country, Taiwan Province, in 1905, and in 1906 or 1907 to Hainan Island. A trial tapping of the old trees in 1953 yielded 10 kg of dry rubber for 90 tappings ; this was a strikingly high yield, compared with the averages of the present seedlings (about 1 kg) and clones (about 3·5 kg) in China. But this record for a single year only is not representative since the tree has not been tapped since 50 years.

Since rubber has been successfully cultivated in China and also there is a demand for it, large stretches of land in southern and south-western Yunnan, at an elevation of about 1,000 m, were transformed into State Rubber Farms. During the last 30 years, rubber cultivation showed a remarkable success. In Dehong Prefecture, for example, most of the rubber trees which grow at an altitude of 800 – 1,000 m, grow well and yield considerably to the dry rubber production of China. There is however, still a certain amount of mortality, due to natural hazards, especially cold damage and mishandling by human beings and animals. In order to provide scientific bases and favourable approaches for a safe production, this paper tries to analyze the positive and negative factors and some key-problems in rubber cultivation at a higher altitude in Yunnan from the point of view of geo-ecology.

Ecological habits and characteristics of rubber trees

Hevea brasiliensis is indigenous to the tropical rain forest in the Amazon Basin at an altitude below 200 m, near the equator. This region is characterized by a high temperature : monthly means between 24 – 28°C, by ample rainfall : annual totals over 2,500 mm, which show a short dry spell only, and by light breezes throughout the year.

1. The author has consulted the Chinese tropical agronomist Mr. Hekang, who has been to Sri Lanka twice to investigate the cultivation of tropical crops and Dr. M. Domroes, professor at Mainz University, West Germany, who has been engaged in agro-climatic research in Sri Lanka for 15 years, with the same answer that the altitude for rubber cultivation in Sri Lanka was about 500 metres.

The soil is deep and fertile and has a good drainage. Rubber trees have been growing for generations in such an environment and thus they have formed an ecological preference to warm, breezy and humid weather and to fertile and well-drained soils. Yet, rubber trees are drought resistant to some degree and their root system is aerobic.

The ecological environment of rubber is different in China to that of the native country of *Hevea*. A significant difference is the lower temperature which occurs in China in winter. Due to strong cold waves which sweep across the eastern Asian Continent in winter and which thus tend to invade the areas of lower latitude to cause a remarkable drop of temperature, it is generally acknowledged that rubber trees will most probably suffer from cold damage as soon as temperature drops below the tolerable lower limit. In slight cases, leaves and twigs get shrivelled, while in severe cases, the whole trunk or parts of it become withered, or even the whole plant may die. Obviously, cold damage to rubber trees is a rather complicated matter. Low temperature is not the only adverse factor to rubber growth, which will be shown later. Rubber growing areas in Southeast China, such as Hainan Island and the Leizhou Peninsula, are frequently attacked by typhoons during summer and autumn, which cause severe wind damage to rubber trees, *e.g.* trunk damage, snaps and windfalls. Some heavy typhoons sometimes can destroy a long standing rubber plantation in several hours (over 80% of trees may get trunk-snapped and uprooted according to observations). Sunshine which was earlier neglected as an agroclimatic parameter for rubber, has been proved as a significant factor related with both, latex production and cold resistance of rubber trees. The relationship between low temperature and cold damage can be described as follows :

Major types of cold damage on rubber trees

According to many observations and research by the author and his colleague (Ailiang, *et al* 1965; Ailiang and Shirong, 1981) cold damage to rubber trees can be classified into four types, *i.e.*, two basical types and two sub-types (Table 1). It can be seen that the abrupt cold damage of the radiation type depends upon the appearance of frost-bite. Generally, a temperature drop below 0° C would give rise to frost-bite ; sometimes a temperature around 1 – 2° C can also cause damage to rubber but not quite seriously. A frost-bite on one morning would bring about chill injury to rubber trees, hence the term of " abruptness ". In contrast, cumulative cold damage of the radiation type (foot rotting) usually appears without frost-bite, but the minimum daily temperature often falls between 0° C (or 2° C) and 5° C, and this will last for 1 – 2 weeks. During this period, the bark at the base of the tree, especially northward bark in a shaded rubber stand, bursts and exudes latex, then begins to die-off. This is known to the local people as " foot rotting". In some cases, the bark dies out without bursting and latex exuding. In this case, the bark will give no latex when pricked. The longer the duration of this kind of weather and the more shady a rubber stand, the more severe " foot-rotting " will be.

Dismal and raw weather can cause two types of advective cold damage. During this period, the daily minimum temperature is not necessarily very low (around 2 – 5°C), but the daily mean temperature is lower (below 10 or 12° C). If this lasts for 1 – 2 weeks, cold damage may develop and the longer the unbroken spell, the more serious the damage will be. It can be seen that advective cold damage is a type of cumulative and energy-exhausting damage. A distinction between short spell windy cold damage and long

Table 1. *Patterns of cold damage to rubber trees*

Type	Sub-type	Weather	Meteorological index	Cold damage
Radiative (clear)	Abrupt (frostbite)	Fine, larger difference in diurnal temp. (> 10 or 15°C)	Min. temp. below 0 or 2° C	Leaf and twig blighting on the first or second day of cold period ; some trees dying whole at a lower min. temp.
	Cumulative (foot rotting)	(ditto)	Daily min. temp. between 10 or 12° C and 5°C, lasting 1 — 2 weeks	Base of trunk especially north-facing bark going dead. usually below 0·2 — 0·5 m. longer the cold period, the severer the damage. Some trees may die in this case.
Advective (overcast)	Short-spell windy cold damage	Overcast, little difference in diurnal temp. (> 5°C)	Daily mean temp. below 10 or 12° C, lasting 1 — 2 weeks with high wind	Spots appearing on tender twigs and spreading to other parts of the tree. Trees facing the wind suffer more seriously than those in a sheltered place. Some trees die in some severe cases.
	Long-spell overcast cold damage	(ditto)	Daily mean temp. below 10 or 12°C lasting 3 — 4 weeks with less wind speed	Nearly the same as above but damage is greater

spell overcast cold damage lies in wind velocity apart from the duration of coldness. The former cold damage is characterized by higher wind speed (daily mean over 2 – 3 m/sec.) within 1 – 3 days in the early stage of cold wave invasion. In this case, rubber trees growing on the leeward side of a slope, owing to the comparatively slow wind speed, will suffer little or no damage for lower wind speed, while those on the wind-swept side will get heavily damaged or even die. When the latter prevails, rubber trees either on the leeward side or wind-swept side will get heavily damaged.

Influence of sunshine upon cold damage on rubber trees and latex production

Whether a rubber tree gets cold damaged or not after a chilly spell depends also upon other factors, especially upon sunshine. Different types of cold damage react differently to sunshine. Brief explanations are as follows :

Sunshine influence on frost-bite

If rubber trees encounter a temperature between 0 – 3°C and then receive a direct bright sunshine in the early morning, the temperature on the surfaces of their leaves and twigs will rise rapidly, resulting in quick blight of the leaves and twigs. These symptoms may appear in the same afternoon or the following day. If rubber trees do not get direct sunshine 2 – 3 hours after a frost-bite, due to other factors or geographical position (*e.g.* to be located on the west side of a steep slope), the temperature on the surfaces of leaves and twigs will rise slowly, but the affected parts of the trees still have time to heel and be able to recover or at least mitigate it. The aforesaid phenomena were witnessed by the author and other researchers in Guangdong and Guangxi Provinces after a frost-bite in January 1955 and in Xishuanbanna, Yunnan Province, after a cold wave in January 1976. But if temperature is below —3°C, serious cold damage will inevitably occur on rubber trees even if they receive sunshine soon after the frost.

Sunshine influence on "foot-rotting"

Main meteorological indices causing "foot-rotting" are given in Table 1. When the daily minimum temperature remains between 0° C (or 2° C) and 5° C which lasts for 1 – 2 weeks without frost, sunshine in the early morning will be of benefit to rubber trees. This has been proved by a series of facts observed :

First, direct sunshine in the early morning can bring the temperature in tree foliage and twigs up to 5° C (which is regarded as the upper limit of low temperature harmful to rubber), *i.e.*, shortening cold duration for the tree that has been troubled by chill to have the functions of its body depressed (*e.g.*, water absorption and transportation processes slowed down), but still not as seriously thwarted as the case of a frostbitten tree with some of the water in its foliage and branches frozen and the functions in its body dislocated.

Secondly, rapid rise of temperature in the early morning tends to boost noon temperature above 18° C, which is regarded as the lower limit of optimal temperature for rubber growth, so that the tree's physiological process, such as photosynthesis, can recover to produce photosynthetic products for the whole plant. Obviously, sunshine in the early morning is conducive to rubber wintering, especially to its resistance against the cumulative, energy-exhausting type of cold damage (*i.e.* "foot rotting", short spell windy cold damage and long-spell raw weather cold damage).

Sunshine influence on advective type of cold damage

Two sub-types of advective cold damage, *i.e.* short-spell cold damage and long-spell raw weather cold damage, are shown in Table 1. In the course of an advective cold wave, even short intervals of sunshine (*e.g.* 2 – 3 hours daily for 2 – 3 days) will obviously increase rubber's resistance to both advective types of cold damage. For example, when advection raw weather had affected the rubber growing area in southwestern Guangxi for 46 days (from 26 Dec. 1967 to 10 Feb. 1977), the temperature in Longzhou County (22·5° N) was higher than that in Hepu County (21·7° N), southeast Guangxi. The mean minimum temperature for the coldest days was 4·7° C for Longzhou and 2 – 3° C for Hepu ; extreme low temperature was 3·1° C in Longzhou and 1·5° C in Hepu ; total accumulated low temperature (calculated by sorting out the days with a mean temperature below 12° C, subtracting the mean temperature of each day from 12° C and then adding up the temperature difference of each day) was 7·36° C for Longzhou and 91·8° C for Hepu during a cold spell. Wind speed in Hepu was also greater than in Longzhou. One may conjecture that cold damage on rubber in Hepu must be heavier than in Longzhou. But the fact was just the opposite. The reason for this was that there occurred several clear days with a total sunshine duration of 81 hours during the 46 days cold spell in Hepu, while the total sunshine duration in Longzhou was only 35·6 hours. As a result rubber in Hepu has received more sunlight for photosynthesis and replenishment of the energy loss during an advective cold spell ; while that in Longzhou suffered more from a longer cold spell and insufficient sunshine, so that it will be seriously frustrated for higher energy consumption with little refill. About 90 – 99% of the cold damages which occurred on the rubber farms in Longzhou County, ranged between degrees 4 – 6[2]), however only 22·4% and 34% respectively on Qianwei and Binhai rubber farms in Hepu. All evidence showed that transient sunshine during an advective cold spell could lessen the extent of cold damage to rubber trees.

Sunshine influence on latex production

Since latex is a product of photosynthesis, the duration and intensity of sunshine should have significant influence on latex production. However, the formation and flow of latex represent a complicated physiological process. Latex production is usually affected by many environmental factors, such as temperature, soil moisture, atmospheric humidity, and wind speed as well as sunshine. It is also influenced by seed variety, soil texture, cultural techniques, etc. Among the affecting factors, sunshine is the most prominent. The monthly sunshine duration and the corresponding latex production have been presented in Fig. 1. It can be seen that latex yield (one tapping per tree) in Jinghong County is lowest from May to August, though during that period temperature is optimal and rainfall adequate. Low latex production may be due to shorter sunshine duration during the rainy season. Both curves in Fig. 1 show double peaks, which underlines the importance of sunshine on latex production. In comparison, sunshine curves of a double-peak type are quite flat for Hainan Island and the curves of latex production yield normally do not appear in double-peak form. It is understandable that for Jinghong County the two peaks of latex yield occur 1 - month later each than those of the sunshine curve ; this is the time the trees need to form, convert and transport photosynthetic products.

2. Cold damage to rubber tree is divided into 6 degrees, namely zero-degree : no damage ; first-degree : slightest damage ; fourth-degree : the whole crown withers and only 1 - 2 metres of the trunk is intact ; fifth-degree : less than 1 metre of the trunk is intact ; sixth-degree : the whole tree dies.

Influence of other environmental factors on cold damage to rubber tree

During the period of rubber wintering, higher wind speeds (above 2 – 3 m/sec.) would reduce the resistance of rubber to advection and radiation coldness. Proof of this are the flat rubber-growing areas on the Leizhou Peninsula and Hainan Island during the 1950s and 1960s : rubber trees sheltered by windbreaks experienced slighter cold damage only than unsheltered trees, and those on the leeward side and closer to the shelterbelts suffered least. In cold-ridden areas, rubber trees on the leeward slopes usually suffered much lesser than those on the wind-swept side at the same elevation. In addition, water stress or water excess in the soil, and especially stagnant water in the root zone, obviously tends to weaken cold hardiness of rubber trees.

The distribution of the rubber growing areas in China at higher altitude and its reasons could be analysed on the basis of geo-ecology.

Geographical distribution of rubber cultivation and its reasons

The author's 30 years' experience on rubber cultivation in China has shown that rubber can be grown at an elevation above 800 m only in the regions west to the 2,000 m contour zone on the southeast side of the Xizang (Tibetan) Plateau (with the Ailao Mountain Range as a typical example), while rubber cannot be established at an elevation above 800 m in the regions east to this contour zone, including Hainan Island, Taiwan Province, and the southeastern Yunnan Province, such as Hekou County (22·5° N, 104° E).

In the mid 1950s, cold damage to rubber could be observed occurring almost every year at an altitude above 300 or 350 m in northern Hainan Island, and rubber trees established above 500 m were damaged. However, in southern Hainan Island rubber could be safely grown at an elevation up to about 500 m above sea level, but serious cold damage was noted at an altitude above 800 m. In the last 20 years, rubber trees have been planted at different elevations of 100, 200, 300, 400 and 500 m in Hekou County (east of the Ailao mountain), southeastern Yunnan Province. It was found that no rubber at an altitude above 500 m could overwinter, and only a small number of those trees at an altitude of 400 m on the leeward sunny slopes survived, while most rubber at an altitude of 300 m got safe through the winter, except those on the wind-swept sides and in wind gaps. In contrast, rubber can be grown on sunny slopes at an altitude of 800 m or even above 1,000 m, in Xishuangbanna, Simao Linchang and Dehong Prefectures, west to the Ailao mountain (northward slopes, especially steeper northward slopes, however, those areas are inhospitable for rubber). What is the reason for such a great difference in the elevation for rubber cultivation in the regions to the east and to the west of the Ailao mountain ? This actually has been analysed by the author and further discussion can be given as follows :

Although Jinghong County (21° 57° N) has almost the same latitude as Qinzhou Prefecture (21° 57° N) and the former is located at a higher elevation (553 m) than the latter (4 m), the mean temperature in winter in Jinghong is much higher than in Qinzhou. Table 2 shows that the mean January temperature is 2·6° C higher in Jinghong (15° C, average for 10 years) than in Qinzhou (21° C). Qinzhou Prefecture encountered exceptionally strong cold air advection in February 1968 and January 1977, when the mean temperature were 9·3° C and 9·2° C resp., which were 7·4° C and 7·3° C lower than those in Jinghong (16·7° C and 16·5° C resp). The difference was even larger between the monthly mean maximum temperatures in the two regions, *e.g.* the mean maximum in February 1967 was in Qinzhou (10·3° C) even 16·3° C lower than in Jinghong (26·6° C) and that in January 1977 by 13·6° C lower. This can be explained as follows : when cold air rushes southwards to reach the south of the Nanling mountain, its thickness (mean thickness of the cold air with high pressure at ground or lower level) usually is reduced to 2,000 – 3,000 m. Since the Tibetan Plateau and other high mountains (with an altitude of above 3,000 – 4,000 m) to the north of Xishuangbanna have blocked the invasion of cold air, the cold air can attack Yunnan only from northeast and east rather than from north. But Xishuangbanna is sheltered by the Ailao mountain range in the east (average elevation above 2,000 m, extending more than 500 km from north-west to southeast without obvious gaps), and mountains in east Yunnan and west Guangxi, which have kept off the front of the cold air, so that it is almost not influenced by the cold air. The front of this cold air is known as the Kunming Quasi-stationary Front. The west edge of the frontal surface (having certain width) nearly coincides with the Ailao mountain range. This line is not only the major climatical divide of south China, but also an important boundary of vegetation.

Table 2. *Comparison between Jinghong and Qinzhou in temperature and sunshine in winter*

	Monthly mean temp. (°C)			Monthly mean max. temp. (°C)			Monthly sunshine (hr.)		
	Annual mean (Jan.1968-1977)	Feb. 1968	Jan. 1977	Year's mean (Jan. 1968 1977)	Feb. 1968	Jan. 1977	Year's mean (Jan. 1968 1977)	Feb. 1968	Jan. 1977
Jinghong	15·6	16·7	16·5	24·8	26·6	26·1	185	210	210
Qinzhou	13·0	9·3	·92	17·4	10·3	12·5	93	13	53

Table 2 also clearly indicates that Xishuangbana, west to the Ailao mountain, is rarely affected by cold air advection and there is no cold front activity even in winter. Therefore, it records more sunny days with a greater sunshine duration and higher daylight time temperature, while the vast area east to the Ailao mountain is under the influence of the Kunming Quasi-stationary Front and South China Stationary Front. Actually, both fronts are branches of the same front of cold air drifting southwards, the former moving from northwest to southeast, the latter roughly from east to west so that there are more overcast and rainy days with less sunshine. When cold winter prevails in Qinzhou (together with the huge areas of Hekou, Nanning, Guangzhou and Zhangzhou, etc.), the difference in sunshine between the regions to the east and west of the Ailao mountain is especially significant ; good examples were seen in February 1968 and January 1977. In February 1968, the total sunshine duration was in Jinghong (210 hrs) 16 times greater than in Qinzhou (13 hrs), while in January 1977 it was in Jinghong (210 hrs) about 4 times greater than in Qinzhou (53 hrs). The difference in sunshine was also reflected in the daily maximum temperature. As mentioned before, in February 1968 the temperature in Jinghong (26·5° C) was 16·3° C higher than that in Qinzhou (10·3° C) and in January 1977 it was 13·6° C higher in Jinghong.

Sometimes cold waves in the east are so forceful that they cross over the Ailao mountain to attack the western region. This situation can be illustrated by Fig. 2, Let h be the thickness of advective cold air layer (east wind, for example) and H be the height of a mountain (running N to S, for example), according to the conservation law of potential vorticity.

$$\text{hence,} \quad \frac{d\,(\S + f)}{d\,(h - H)} = 0$$

where § is the vorticity of air column, f the Coriolis parameters ($f = 2\ \Omega\ \sin O$, where Ω is the angular velocity of the earth's rotation, and O the latitude). When the cold air-flow crosses over the mountain, its thickness decreases and (§ + f) in the equation should be reduced accordingly. When f remains constant for east wind, § will decrease with h. This means that the cold air-flow will make an anti-cyclonic turn, *i.e.*, it will deflect northward, which can increase f and further diminish and in turn intensify the anti-cyclonic deflection. In consequence, a local anticyclonic circulation will be brought about. After crossing over the Ailao mountain, the air-flow will sink with an anticyclonic vorticity — the anticyclinic vorticity will reduce when sinking — to cause the front and the accompanying weather to dissipate. In fact, some cold air in winter is very strong, and its front can sweep over the Ailao mountain to bring a cloudy or rainy weather in Xishuangbanna, which usually lasts only 1 – 2 days (sometimes 3 days) and then turns fine. However, the cloudy or rainy days in winter in the region east to the Ailao mountain, such as Longzhou, Qinzhou and Guangzhou, often lasts for 1 – 2 weeks, or even 40 days.

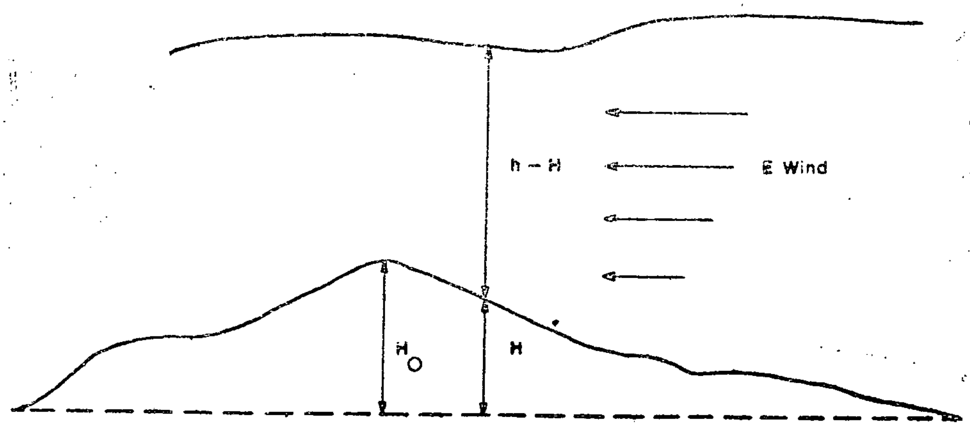


Fig. 2. Advective cold air climbing over the (Ailao) mountain.

The reasons for higher winter temperature in Xishuangbanna as compared with the region east of the Ailao mountain (*e.g.* Qinzhou) can be summed up as follows :

(i) The range of Ailao mountain blocks the cold air advection from the northeast, so that no advective low temperature occurs or there is not much drop in temperature by cold air advection in Xishuangbanna during winter ; (ii) Owing to the sheltering provided by the mountain range, Xishuangbanna is controlled mostly only by a single air-mass in winter, so that it has more clear days and higher temperature, especially the daily maximum temperature, than those in the eastern region ; (iii) Even if strong cold air crosses over Ailao mountain or other mountains occasionally, the dynamic effect of mountain ranges will soon dissipate the front and its rainy or cloudy weather.

As for the adventive cold damage the rubber trees mentioned earlier, Xishuangbanna, Dehong, Linchang, etc. have no or rarely have long-spell raw weather causing advective cold damage. This has been evidenced in the 20 years' practice of rubber cultivation. There was an instance in the winter between 1975 — 76 when several dozens of rubber trees established in a wind gap at an altitude of over 1,000 m (relative height being about 100m) got blighted crowns or half blighted crowns and trunks due to cold damage on the Guangpin State Farm, Xishuangbanna. This symptom has some resemblance to the sub-type of short-spell windy cold damage of advective type of cold damage described previously. It was a rare case that rubber was planted in the wind gap in the mountains since the wind speed in winter in west Ailao mountain is very weak usually. Nevertheless, quite a few rubber trees (PB 86, a cold-sensitive clone) growing at the same elevation on the leeward side of the contour terraces in the above-said place showed no sign of cold damage. So it can be said that rubber trees in west Ailao mountain rarely suffer from advective type of cold damage, but from one of radiative type (frost-bite and foot rotting).

Now let us turn back to the question why rubber cannot be planted in the high elevation areas east of the Ailao mountain. Take Hainan Island for example, due to the higher wind speed during a cold wave in winter (often over 3 m/sec. in the first 2 – 3 days), which accelerates with higher altitude to result in a lower mean temperature and consequently a raw weather lasting for 1 – 2 weeks or longer, rubber trees grown on the slope at a higher altitude (*e.g.* over 500 m) can hardly survive for cold damage of the advective type.

Diversity of cold damage to rubber tree on different hill-sides.

Rubber cannot be grown in all the areas west to the Ailao mountain ; suitable are the plots which possess certain conditions of specified topography and altitude. First the conditions of topography will be discussed which mean the diversity of rubber wintering on the different hill-sides. There are two examples :

(i) A great number of rubber trees suffered cold damage in Xishuangbanna and Dehong region during the winter of 1975 – 76. The situation of the typical plots on two state farms are listed (Table 3). This shows the diversity of cold damage to rubber on different hillsides. The phenomena can generally be seen in the rubber-growing areas of Yunnan Province.

Table 3. *Diversity of cold damage to rubber (foot rotting) on different slopes*

Location :	Location :
Jinghong Country	Ruili Country (Boluo mountain)
Degree of seriousness of cold damage on different slopes	Degree of seriousness of cold damage on different slopes
E S W NE	N NE E SE S SW W NW
5·3 0·1 1·0 3·5	3·6 3·5 2·78 0·54 0·24 3·84
cultivar : RRIM 501 planted in 1965. 30 trees in each slope surveyed in 1976	cultivar : PB 86. 50 trees in each slope surveyed in 1976

(ii) Rubber trees planted on different slopes in the same mountain in Dongfong State Farm, Jonghong County, suffered cold damage differently (see Fig. 3).

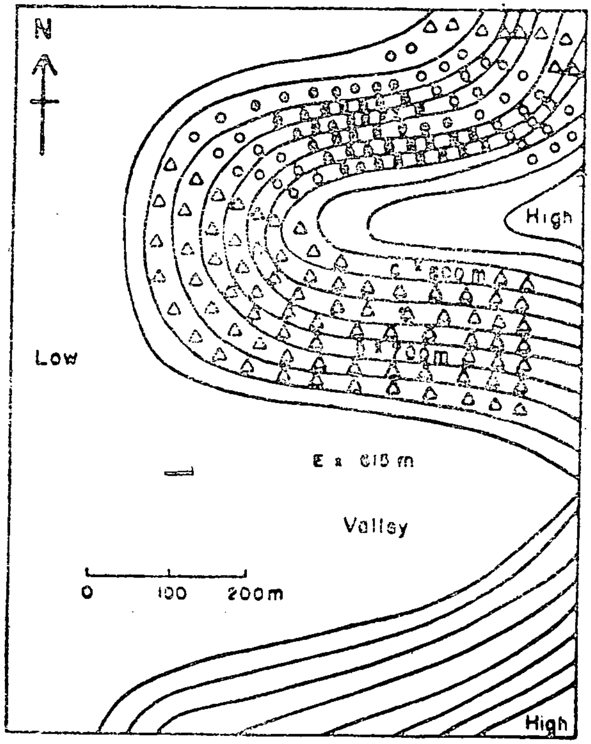


Fig. 3. **Contrasts in the degree of cold damage to rubber trees on different slopes in Xishuangbanna :**

△ — light or no damage ;

○ — moderate damage ;

⊖ — trees killed by heavy damage ;
the letter C, D, E, F represent location of the topoclimatological observing stations.

The author and his colleagues (Ailiang, 1981) carried out micro-climatic observations on the north and south slopes of this mountain in January 1978, finding that temperature diversity of the north and south slopes between the morning and evening is distinct, the nearer to the surface of ground, the more distinct was the diversity. It can be explained, based on the difference of sun-shine on different hillsides in winter, the difference of air temperature very near to the ground further explains why the rubber trees will not suffer cold damage (foot rotting) on south and west slopes, while on the north slope they suffer heavily or almost die off in severe winter.

The influence of the elevation upon the growth of rubber, latex production and cold damage

The elevation means the altitude above sea level and the relative height to a vicinal valley.

The effect of altitude above sea level on growth of rubber

The climatic characteristics on a hill-slope at higher altitude, as compared with the basin at a lower altitude, are relatively lower mean temperatures, insufficient sunshine duration and higher wind speeds, which stunt rubber trees in growth on higher altitude of a slope (Table 4). The temperature and sunshine duration of two rubber-growing plots (Atu village and Nangjingli) with high altitude and the nearly basin in growing season (May to October) are listed (Table 5).

Table 4. *The average rate of growth of rubber trees at different altitudes*

Locations	Altitude	Average rate of growth in diameter (cm/year)	Years of growth
Manjuwa	920	2·32	6·5
Atu village	1060	1·92	6·5
3rd Sub state farm of Mengsa	1140	1·02	15
Nanjingli	1310	1·05	19
Nanrushan	1420	1 01	5·5

The problem of latex production

The old rubber tree growing on Fenghuang Mountain (980 m. a.s.l.), Yinjiang County, has given 90 trial tappings in 1953, gaining a high yield of 10 kg dry rubber. But it was thought that, not having been tapped for decades, only one year's yield can hardly stand for anything. Other rubber trees planted on Atu village in early 60's had been tapped in late 60's to the early 70's, yielded normally. Later the tapping stopped due to the difficult transportation. But tapping was resumed in 1982 – 83 and said to have a high yield (no records available). Therefore, latex production of rubber trees at high altitude (above 1000 m) does not drop. The reasons are probably : (i) The lower temperature at high altitude is of no benefit to the growth of rubber, but of benefit to the latex flow. Moreover, insufficient sunshine is not advantageous to carry out photosynthesis, but because the rate of rubber's photosynthetic conversion is rather low one tapping every 2 days yield about 100 g dry rubber, consumption of photosynthetic product is less, the latex production cannot be affected greatly. (ii) More rainfall at high altitude and higher humidity are optimal advantages which can remedy a part of disadvantages mentioned above. In total, the scientific data are not sufficient and will be proved further.

Elevation effect on the cold damage of rubber trees

In Xishuangbanna in winter, mean temperature drops about 0·6° C every 100 m, (Ailiang, 1982) but the daily minimum temperature does not fall with the altitude. Owing to many fine and cloudless days in winter (about 85% days are clear during Dec., Jan., Feb.) the temperature on the slopes in the mornings and evenings is 1 — 3° C, even 5° C higher than that at the bottom of the valley and the basin. Rubber trees, grown on the north and west slopes (relative height about 100 — 400 m), are more secure than that at the bottom of the valley and in the basin.

Table 5. *The monthly mean temperatures and sunshine hours of two plots located at high altitudes compared with those near the basins during rapidly growing season (May — October)*

Location	Altitude (m)	Monthly mean temp. (°C) May	June	July	Aug.	Sep.	Oct.	Mean May-Oct.	Sunshine hours May	June	July	Aug.	Sep.	Oct.	Total May-Oct.	Period of records
Atu village	1060	22·9	22·3	21·5	21·6	21·6	19·9	21·6	189	110	100	108	144	129	780	1960 - 64
Ginghong (basin)	553	25·5	25·5	25·0	24·8	24·4	22·7	24·7	220	150	143	161	193	167	1036	1960 - 64
Nanjingli	1310	21·4	21·4	21·3	21·0	20·9	18·4	20·6								1979 - 80
Ruili (basin)	776	25·2	24·8	24·3	24·3	23·8	20·5	23·8	270	160	136	148	179	186	1068	1979 - 80

REFERENCES

JIANG AILIANG, et al, (1965). Cold damage to rubber in South China (Printed material published by Geo-Research Institute).

JIANG AILIANG AND Li SHIRONG (1981). Relationship between topographical micro-climate and rubber cold damage, *Agro-meteorology* 1981 – 1.

JIANG AILIANG, (1981). Temperature inversion and vegetation inversion in Xishuangbanna. *Mountain Research and Development*, **1**, No. 3 – 4, 275 – 280.

JIANG AILIANG, (1982). On the variation of temperature with height in tropical China and its effect on rubber tree cultivation. *Climatological Note* No. 29, 15 – 18.

DISCUSSION

Q — ABDUL MAJEED, RRI, Indonesia : You grow PR 107 in Hainan in the South China Academy of Tropical Crops. It grows very well in that area. PR 107 is very good, healthy, did not show any signs of *Phytophthora* in the leaves or stems there. PR 107 was selected at high elevations in West Java at about 900 m in a very unique climate. This clone is outstanding and high yielding and has a very thick bark and is wind resistant. As you mentioned you have some experiments in the Yunnan province, I wonder whether you have also experience with this PR 107 in such cold weather. I saw at Hangiam C.T. 1 resist in - 1 °C and also Hican 1. I wonder if this PR 107 did similarly in that area. Do you have similar experience with PR 107.

A — JIANG, AILIANG, China : The climate in the Western part of Tropical China in winter is very dry, but the Eastern part of Tropical China, the winter is very wet. So the resistance of rubber tree to cold is quite different. And in the Western part of Tropical China such as Sisamala 90% of days in winter has clear weather. So even with severe cold weather from North China modified by the topography, the humid and overcast days last only 2 or 3 days. The rubber tree can resist short periods of wet and cold weather. But in the Eastern part such as Hainan Island the wet and overcast and poor weather last for 2 or 3 weeks and even more than 1 month. Under this condition the rubber tree in the North part of Peninsular sometimes has severe winter and get cold damage.

Q — ABDUL MAJEED, RRI, Indonesia : Have you got any experience with PR 107.

A — JIANG, AILIANG, China : We have PB 86 and also PR 107 in higher altitudes. We have four main clones viz. PB 86, PR 107, EG 1 and RRIM 600 in very rich high elevations.

Q — H. Y. CHAN, Malaysia : I would be interested to know whether you have got any new figures on rubber tree yield for the altitude of 1000 m and above.

A — JIANG, AILIANG : Most records of rubber tree yield are not normally taken. But last year the Institute of Tropical Crops of Yunnan Province sent a person for records. I am sorry I did not bring any records. Some farmers told me, in the rubber tree, in high altitudes the yield of latex production is normal as in lower altitude such as in the basin, no great difference.

Q — ANON : Measures taken to prevent the effect of frost on rubber trees, could you expand a little more on what measures were taken and particular experiments taken to protect, the tree from frost.

A — JIANG, AILIANG, China : The measures we used were to carefully extract small areas such as on the middle heart of a mountain slope on the southern slope where the micro climate is quite good for rubber tree growing. As shown in the slide on the northern slopes all rubber trees died covered by frost. But in the south facing slopes there is no frost. This is the most remarkable contrast.

VARIABILITY IN COMMERCIAL YIELDS OF CLONE PB 86

By

W. N. WICKREMASINGHE
(*Rubber Research Institute, Sri Lanka*)

ABSTRACT

PB 86 yields obtained from 103 estates covering the entire rubber area were used for an analysis of the extent of variation and for a better estimate of the yield of the clone for each year of tapping. Results are presented for four selected sites viz. Kegalle, Kalutara, Kurunegala, Galle and Matara. Finally, estimates of PB 86 yields for the entire rubber area are presented with possible error limits of the estimates.

INTRODUCTION

Budded rubber shows a high degree of tree-to-tree variation for yield. This variation can vary from clone to clone. Also for the same clone, considerable variations exist from plot to plot, field to field and site to site.

If our interest is to study the variability of yield in kilograms per hectare of a particular clone over the whole life span, we need to carry out an experiment with one clone planted and managed under the same conditions and continue it for about 30 years, which is the normal economic life span of a rubber tree. This is not practicable. Even if this can be done, it does not give a general idea of the variability over the entire rubber growing area and under varying conditions.

Therefore, the best alternative is to look at commercial yields. Also, the clone PB 86 is the most popular clone and it can be found in almost every estate in Sri Lanka. It is felt that this approach would be the best to study the variability of PB 86 yields since, it is the commercial yield that is used for many purposes. One important fact is that a large sample needs to be drawn from the entire rubber area and this has not been done before in Sri Lanka, for a particular clone.

The objective of this paper is to study the yield variability of the clone PB 86, from a considerably large sample of commercial estates covering the entire rubber area. An attempt has also been made to obtain a more representative estimate of the yield in kilograms per hectare of PB 86, in each year of tapping, also providing the error limits of the estimation.

MATERIALS AND METHODS

Data for the study were collected through a mail survey by sending a questionnaire to 80 estates under the Janatha Estates Development Board (JEDB) and 107 estates under the Sri Lanka State Plantations Corporation (SLSPC). Estates under the JEDB covered the four regions : Avissawella, Badulla, Kegalle and Kurunegala while the estates under SLSPC covered the five regions Balangoda, Kalutara, Ratnapura, Matale, Galle and Matara. The list of estates was obtained from the Rubber Industry Master Plan Study (1979).

In the questionnaire, it was requested to give details of clone PB 86 only. These details include yield records (kg/ha) for the last 10 years (1974 — 1983) for each division, and also the age of the plantation, year of the commencement of tapping, hectareage, etc. From a total of 187 estates, 103 estates responded. This was more or less like a randomly selected sample. Badulla and Matale regions were excluded from the analysis since there were only a few estates from those two regions.

As a first step, for each region considered, yield records were grouped according to the age of the plantation. These records came from different estates and also different divisions, but in the same region. Then for each year beginning with the sixth, a mean and a standard error of the mean were calculated using the number of observations falling into each category, that varied with the age and also region.

Two approaches were used to estimate these means and errors. One was to eliminate unrealistic and very low yield figures for the year concerned, which may be due to so many factors such as poor stand per hectare due to diseases or wind damage, rain interference, different management practices, recording errors etc., before analysis. The other was to take into account all these factors and without eliminating any of the data, calculating the mean and standard error which gives a measure of the variability of the estimated average. Estimates under the first approach can be taken as estimates of yield under normally expected conditions. But in reality, conditions do not prevail as expected. Therefore, it is expected that the second approach, viz. to consider all the available data for analysis, gives more general estimates.

For the first approach, results are presented only for four selected areas. They are Kegalle, Kalutara, Kurunegala, Galle and Matara. Galle and Matara are taken together as one region.

RESULTS AND DISCUSSION

Average yield of PB 86 (kg/ha) for the years 6 through 26, after planting, are given separately for the four regions, Kegalle, Kalutara, Kurunegala, Galle and Matara in Table 1. Standard errors of the estimated averages (Snedecor and Cochran, 1980) and also the number of observations used to obtain these estimates are given in Table 1.

Estimates given in Table 1 are the yield estimates under normally expected conditions. There were no data available for Kurunegala region for the sixth year after planting. This may be due to the fact that normally in that region it would take about 7 years for PB 86 to come to tapping.

It is evident from the figures in Table 1 that we cannot separate out one region which gives higher yields generally over all years. Also, the yield range for the four regions vary considerably with the year, without any definite pattern. One would observe relatively small standard errors in Kegalle and Kalutara regions due to availability of more

Table 1. *Average yield of PB 86 (kg/ha)*

Age (years)	Kegalle			Kalutara			Kurunegala			Galle & Matara		
6	374	(37)	32	392	(27)	24		—		263	(87)	8
7	522	(43)	50	422	(30)	71	448	(164)	3	435	(78)	20
8	938	(50)	33	684	(27)	53	499	(164)	3	610	(80)	19
9	1213	(52)	30	813	(21)	53	373	(87)	5	779	(77)	15
10	1154	(58)	33	974	(33)	33	523	(106)	5	969	(108)	11
11	1316	(42)	20	946	(61)	43	941	(253)	5	984	(129)	7
12	1224	(36)	34	1166	(74)	24	932	(233)	6	1293	(57)	5
13	1277	(57)	43	1191	(59)	29	947	(149)	8	1148	(57)	6
14	1248	(38)	48	1347	(83)	26	1027	(103)	9	1242	(71)	12
15	1243	(36)	52	1348	(37)	25	1237	(63)	7	1265	(46)	19
16	1305	(34)	50	1356	(36)	29	1219	(80)	12	1181	(33)	25
17	1184	(33)	72	1365	(29)	35	1520	(52)	6	1107	(36)	35
18	1224	(27)	62	1186	(31)	61	1395	(79)	9	1153	(41)	40
19	1125	(26)	90	1296	(25)	52	1363	(87)	13	1058	(35)	51
20	1266	(36)	53	1134	(29)	89	1404	(95)	10	1129	(42)	46
21	1191	(31)	76	1113	(29)	95	1303	(86)	13	988	(46)	64
22	1120	(34)	84	1132	(31)	91	1338	(93)	12	1193	(63)	37
23	1285	(38)	63	1239	(34)	81	1646	(94)	8	1081	(47)	46
24	1420	(47)	49	1343	(41)	85	1655	(72)	9	1317	(68)	30
25	1405	(41)	51	1404	(46)	75	1655	(78)	8	1217	(74)	27
26	1392	(51)	47	1392	(39)	78	2095	(167)	5	1120	(90)	20

(Region: Kegalle, Kalutara, Kurunegala, Galle & Matara)

NOTE :— Magnitude of the standard error of the estimated average is given within brackets. Underlined figure is the number of observations used for obtaining average.

observations compared to the other two regions. A definite pattern of a yield curve over the years common for all four regions could not be observed. This suggests, the value of considering all the available data (second approach mentioned earlier) to get a general picture of the yield pattern, because of the high variability in commercial yields.

Table 2 shows the average yield of PB 86 (with standard errors) for a randomly selected year of tapping (13th) for the estates in four regions considered, and also grouped according to the elevation and number of rainy days.

Table 2. *Average yield of PB 86 — 13th year of tapping (kg/ha)*

		No. of rainy days					
		≤ 200			> 200		
ELEVATION (M)	≤ 100	1165	(36)	38	1209	(39)	34
	101 — 200	1188	(38)	34	1247	(51)	10
	> 200	1094	(86)	9	1111	(143)	3

NOTE :— Figures within brackets are the magnitudes of standard errors. Underlined figures are the number of observations used for obtaining averages.

Number of rainy days is an yearly average obtained using data for 10 years (Master Plan Study, 1979). A higher yield was observed for areas with average number of rainy days greater than 200 compared to less than 200, in general. This can generally be expected since wet areas give higher average yields than dry areas. On the other hand, a large number of rainy days for any given year decreases the total yield expected for that year. Table 2 also shows a comparatively low yield for high altitudes.

Another interesting feature of the variability of commercial yields of PB 86 can be seen in Table 3. This table shows the average yield for a randomly selected year of tapping (13th) for a particular estate.

Table 3. *Average yield of PB 86 — 13th year of tapping, Pallegama Estate (kg/ha)*

Data	Mean	Std. error	COV
1066, 1029, 875, 802, 926 1074, 1180, 1330, 885, 1814 1131, 1397, 1198, 1001, 1603 1372, 1271	1174	65	22·8

It is evident from Table 3 that even for the same estate, same clone, same year of tapping, a considerable variation exist from field to field. For this particular estate, Pallegama, for the 13th year of tapping an average of 1174 (kg/ha) was observed. But the yields ranged from 802 to 1603 kg/ha showing a 22·8% coefficient of variation (Snedecor & Cochran, 1980).

A plot of average yield of PB 86 for the sixth through 30th year after planting, obtained from a large sample covering the entire rubber growing area in Sri Lanka is given in Fig.1. In computing the averages and their standard errors, all the available data were used without eliminating any of them. Because of the large sample, the effects from very low and very high figures to the variability get cancelled out and finally we obtain a yield curve which is more representative with respect to estimates of yield in each year.

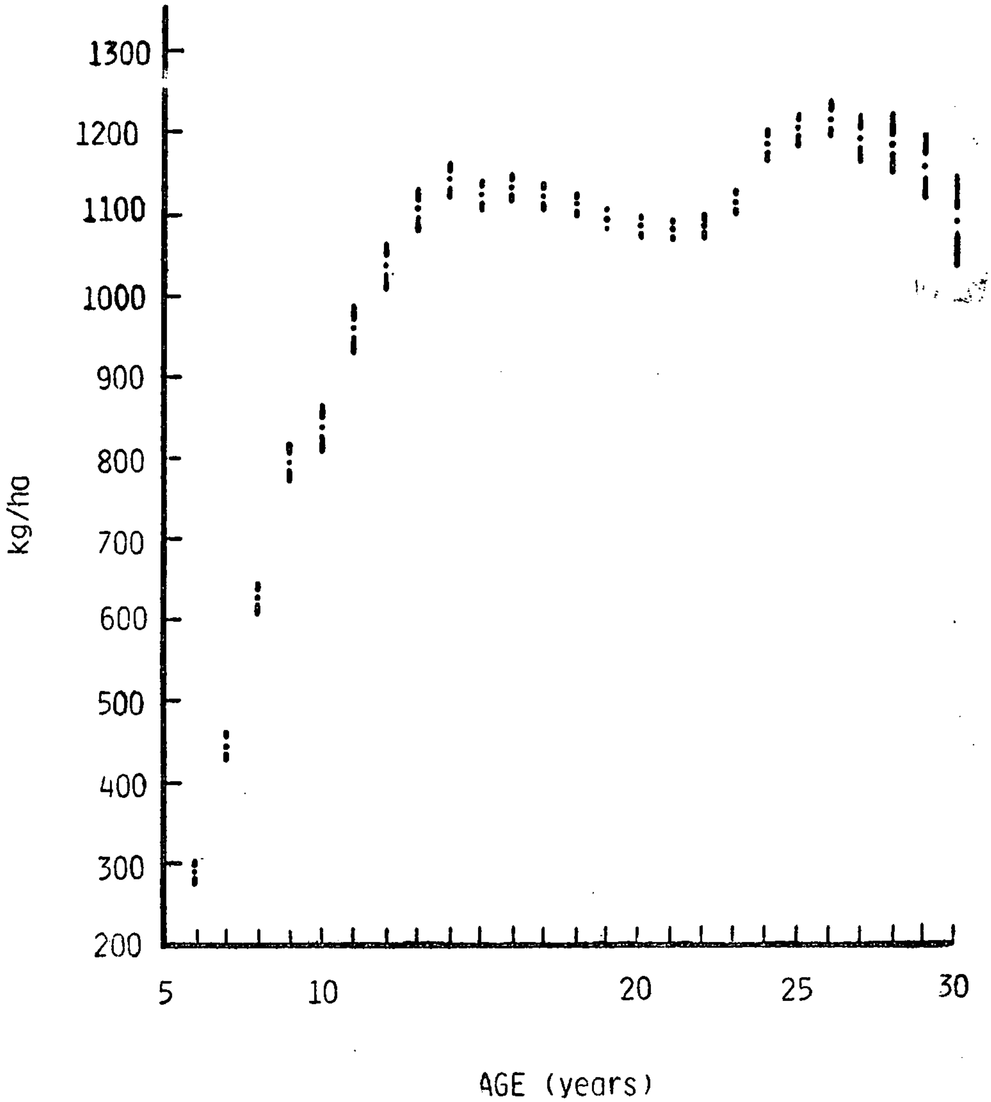


Fig. 1. Average yield of PB 86 with standard error limits

The reason for observing relatively consistent yield figures (hence, small variability) as shown by Fig. 1, during the first 3 years of tapping may be that the trees are tapped on Panel B-1. There seems to be very little variation from estate to estate in this respect. Tapping on panels both B-1 & B-2 and changing over from B-1 to B-2 may have caused relatively higher variability in yield during the next 5 years. Fig. 1 shows that there is a considerable variation from estate to estate with respect to tapping during these 5 years. After a maximum yield is reached around the nineth year of tapping, the next 10 years which follow, seem to give generally a steady yield with little variation irrespective of the estate. This may be due to the reason that most estates tap on renewed bark and employ the same tapping system (S/2, d/2) during these 10 years. Fig. 1, shows that the intensification starts around the year 23 (Liyanage & Peries, 1984). It is evident from the graph that the yield variation from estate to estate becomes higher during this period. An obvious reason for this may be the different tapping systems practised by different estates.

Finally, in comparing the two approaches used in analysing results in this study, one could see the importance of the second approach, *i.e.* to use all the available figures whether they are too low or too high. Without trying to obtain estimates of yield under "normally expected" conditions, and without sticking to a particular area or region, the method of letting data speak for themselves, hence giving a more reasonable picture of the situation should be considered important. A more realistic estimate of PB 86 yield (for any given year of tapping) which takes into account all the factors contributing to it, seems to be, generally, lower than expected by many people.

ACKNOWLEDGEMENTS

I wish to thank Messrs. R. A. P. Abayapala and L. T. Pieris and Miss J. D. Nandani for their kind assistance in analytical work. I also wish to thank Dr O. S. Peries Director, RRISL for his ideas that made me interested in the topic and Mr D. M. Fernando for valuable suggestions. Thanks are also due to Dr Chandra Samaranayake who helped me interpret some of the results.

REFERENCES

ANON, (1979). *Report on the Rubber Industry Master Plan Study*, 3, Part C. Commonwealth Development Corporation, London.

LIYANAGE, A. de S. AND PERIES, O. S. (1984). *A Practical Guide to Rubber Planting and Processing*. Rubber Research Institute of Sri Lanka.

SNEDECOR, G. W. AND COCHRAN, W. G. (1980). *Statistical methods.* Iowa State University Press, Iowa.

DISCUSSION

Q — H. P. SMIT, Netherlands : I recall from one of your last slides the influence of rainfall is lower when the altitude is higher in the influence on the yield. Because the altitude is higher the significant difference between the two columns reduced. If that is true can you clarify.

A — W. N. WICKREMASINGHE, RRI, Sri Lanka : It is actually not the rainfall it is the number of rainy days given. I obtained this data from the Master Plan Study given for average of 10 years. Total number of rainy days for each year (average for these 8 years) are given.

SESSION 3. EXPLOITATION AND YIELD STIMULATION

NET PHOTOSYNTHETIC ACTIVITY AND ITS RELATIONSHIP WITH POTENTIAL PRODUCTIVITY OF SOME SELECTED *HEVEA* CLONES

By

A. NUGAWELA AND R. K. ALUTHHEWAGE

(Rubber Research Institute, Sri Lanka.)

ABSTRACT

A method for measuring net photosynthetic activity of Hevea *clones, using leaf sections obtained from leaves detached under water is described. Preliminary studies to observe the photosynthetic behaviour of detached* Hevea *leaves were done to standardise the material to be used when comparing CO_2 gas exchange rates of different clones. Net photosynthetic rates of five selected* Hevea *clones were measured and possible correlations with field productivity were worked out.*

INTRODUCTION

Great differences in net photosynthesis between many species and varieties have been discovered (Zelitch, 1971). Such differences have been related to the resistances to CO_2 transfer from atmosphere to carboxylation sites, and also to photorespiration turned on by light.

Among hundreds of rice selections under trial, two of the high yielding varieties had as one of the parents a variety whose leaves showed highest rate of net photosynthesis among fifty varieties tested showing genetic regulation of net photosynthetic rates (NPR) (Chandler, 1969). Net photosynthesis by single leaves of twelve soyabean varieties was compared with their seed yield outdoors and the average yield was generally higher in varieties with higher rates of CO_2 absorption (Curtis *et al*, 1969). Hence, high productivity has been shown to be sometimes associated with high rates of CO_2 assimilation by single leaves in a stand.

Most workers have used individual leaves attached to the intact plant for NPR measurements (Hesketch and Mass, 1963 ; Holmgren *et al*, 1965 ; Menz *et al*, 1969). In studies carried out by Hesketch (1963), to determine photosynthetic rates of some woody plants, used leaves which had been excised under water in the field, without any drop in photosynthetic rates before and after excision. Tregunna (1966) studied the effect of O_2 on rates of photosynthesis and photorespiration using detached tobacco leaves. Leaf disks are also commonly used in such studies although the method does not directly reflect natural conditions as the chamber – air flow method does (Aoki, 1981).

Samsuddin and Impens (1978) have compared NPR of four clonal seedlings and the same authors in 1979 have studied photosynthetic rates and diffusive resistances of seven *Hevea* clones using single attached leaves placed in a Siemens Sirigor chamber. In our studies it was attempted to find methods to examine gas exchange rates of different *Hevea* clones in the laboratory using leaf sections obtained from leaves detached under water.

Presently new clones are recommended for commercial planting only after monitoring the field performance of the clones for at least 20 years. During this period vigour of growth before and during tapping, yield by microtapping during immature phase and later by test tapping are looked into.

Studies on more fundamental characteristics like net photosynthetic rates could be useful to understand the physiology of the tree and latex production. Information on these aspects could be useful in crop improvement and in early selection of high yielding clones.

MATERIALS AND METHODS

Differential CO_2 measurements were done using an Infra Red Gas Analyser (Type 225 Mark II, The Analytical Development Company Ltd.,). A 1000 W Halogen lamp was used as the light source. A 15 cm thick water jacket was placed between the light source and leaf chambers to serve as a heat filter. Temperature in the leaf chambers were maintained at 27°C. Light intensity was measured using a LiCor Quantum Sensor and was maintained at 800 μ E $m^{-2}s^{-1}$. The source of CO_2 was atmospheric air and to ensure a uniform supply of CO_2 to the leaf chambers, the air was passed first into a 10 litre reservoir.

The leaf chambers were constructed from pyrex boiling tubes. Gas was led to and from the chamber through an inlet and an outlet respectively, made of glass tubings as shown in Fig. 1. A and B in Fig. 1 are air-tight rubber caps which can be readily removed and replaced to insert leaf samples.

Excision of leaves from plants and excision of leaflets from a leaf was done under water. Leaf sections from leaflets (Fig. 2), were obtained while the leaflet petiole was kept under water. Just before photosynthetic rate measurements the petioles of leaf sections were recut under water.

NPR Determined using leaf sections instead of entire leaves

Five plants (grown in pots in the open) of clone IAN 710 were sampled at random. From each plant 10 leaves were detached from the same whorl and were grouped into two sets of five each (one group with small leaves). From the small leaves entire middle leaflet was used and from the other a section from the middle leaflet was used for NPR measurements. Leaf sections were obtained as described earlier.

Effect of area of leaf section on NPR

Ten leaves were detached from the same whorl (flush) of a young rubber plant. Leaflets were excised and were separated into five groups of five leaflets each randomly. From the five leaflets in a group leaf sections of 6, 8, 10, 12 and 14 cm² were taken and NPR measurements were done simultaneously using leaf chambers in uniform condition according to a 5 X 5 latin square design. The experiment was repeated three times using the clone LCB 870.

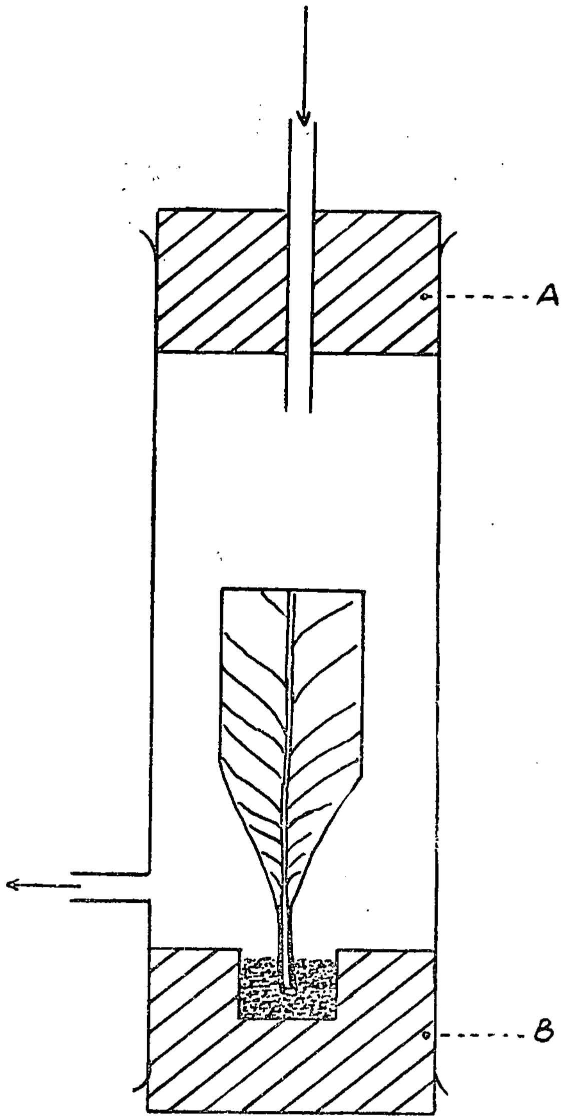


Fig. 1. A sketch of a leaf chamber.

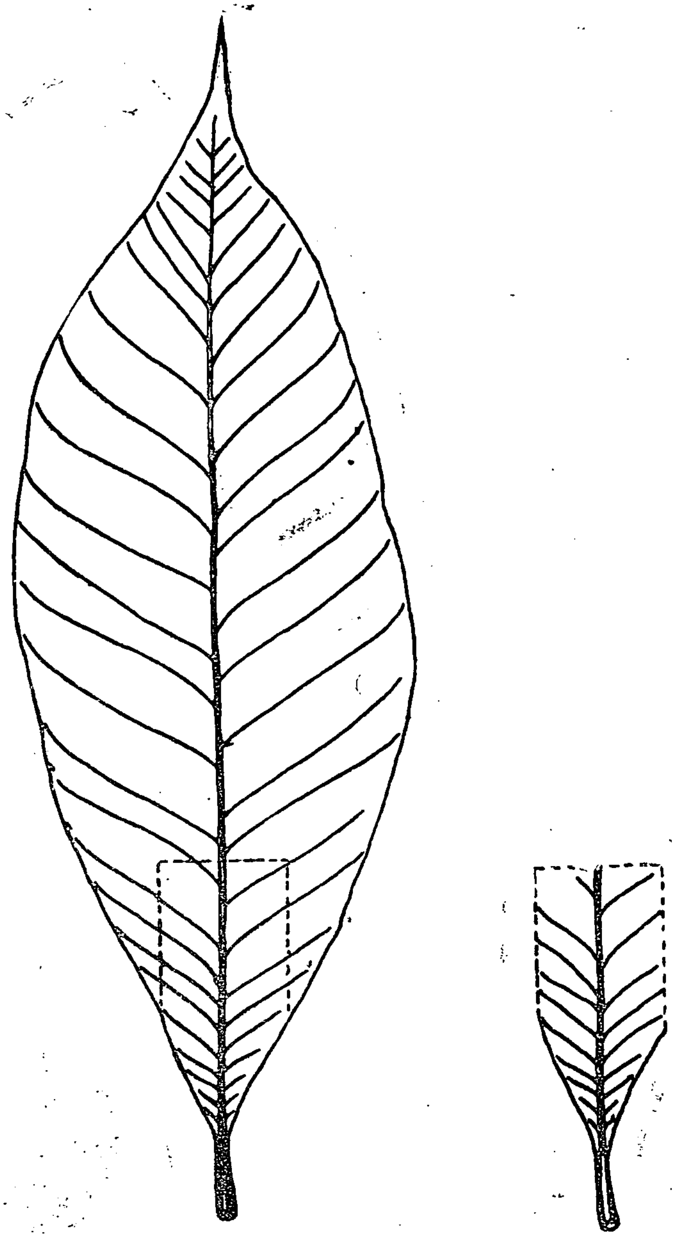


Fig. 2. A sketch of an entire leaf and a leaf section.

Effect of air flow rate in the leaf chambers on photosynthetic rates

Ten leaves were detached from the same whorl of a young rubber plant. Leaflets were excised and were separated into five groups of five leaflets each randomly. Leaf sections obtained (10 cm^2) from each group were used to measure NPR at different air flow rates viz., 200, 300, 400 and 500 ml/min. The experiment was done with clones RRIC 52 and IAN 710.

Diurnal fluctuation of NPR

Five trees of clone RRIC 45 were selected. From each tree one whorl having healthy leaves to obtain leaf samples was selected. At different times of the day viz., 8-00 a.m., 10-00 a.m., 12-00 Noon, 2-00 p.m., and 4-00 p.m., one leaf was detached from each plant from the selected whorl for NPR measurements. Experiment was repeated using clone LCB 870.

Effect of pre-treatments on photosynthetic capacity

Five young rubber plants of clone LCB 870 were selected. From each tree one whorl having healthy leaves was selected. One leaf was detached from each plant from the selected whorl and the leaflets were excised. From each leaf one lateral leaflet was used for NPR measurements immediately and the other was incubated in dark at 25°C for 24 hours prior to NPR measurements. Leaflets were first placed in an air tight container with petioles dipped in water before placing in the incubator. Similarly a 24 hour light pre-treatment (25 $\mu E\ m^{-2}\ s^{-1}$) at 25°C and light or dark pre-treatments for short durations ranging from 0 to 6 hours were given before NPR measurements.

Photosynthetic capacity of leaves in different whorls of young plants

A young tree having five leaf whorls was selected. Five leaves were detached randomly from each whorl. The middle leaflets were excised as described earlier and were kept separately. NPR was determined in five leaflets (one from each whorl) at a time, according to a 5 × 5 latin square design. Experiment was done using leaves of two different clones GT 1 and RRIM 600.

Net photosynthetic rates of some selected *Hevea* clones

Attempts were made to compare NPR of five different *Hevea* clones. Test plants were grown in the open and were distributed randomly in the experimental area. Leaves of similar age were detached under water and a two hour light pre-treatment was given at 25°C prior to NPR measurements.

RESULTS

NPR determined using entire leaves and leaf sections of the clone IAN 710 was 6·692 and 6·311 mg $CO_2\ dm^{-2}h^{-1}$, respectively. A simple paired 't' test showed that there was no significant difference in NPR determined by the two methods.

When leaf sections of different sizes were used to measure NPR (air flow rate 500 ml/min) smaller leaf sections exhibited high capacities, although the differences were not significant (Table 1).

Table 1. *Effect of area of leaf section on NPR (mg. CO_2 dm^{-2} h^{-1})*

Clone	Leaf area (cm^2)				
	14	12	10	8	6
LCB 870	9·400	10·551	11·791	11·570	11·490

There is evidence for a positive linear relationship between NPR and air flow rate at leaf chamber (Table 2).

Table 2. *Effect of air-flow rate on NPR (mg. CO_2 dm^{-2} h^{-1})*

Clone	Air flow rate (ml/min)			
	200	300	400	500
RRIC 52	4·997	5·830	5·810	6·548
IAN 710	8·275	9·445	9·217	10·941

Diurnal fluctuation of photosynthetic capacities showed a similar pattern (Table 3) in the clones LCB 870 and RRIC 45 tested. Photosynthetic capacity is shown to be at an optimum when leaves were detached around 10·00 a.m. and decreased slightly with time.

Table 3. *Diurnal fluctuation of NPR (mg. CO_2 dm^{-2} h^{-1})*

Time	0800 h	1000 h	1200 h	1400 h	1600 h
RRIC 45	9·276	9·502	9·318	9·143	9·001
LCB 870	11·496	11·704	8·707	8·448	7·858

A 24 hour dark or light pre-treatment at 25°C decreases the photosynthetic capacity of the leaves significantly (Tables 4 and 5).

Table 4. *Effect of dark pre-treatment on NPR (mg. CO_2 dm^{-2} h^{-1})*

Clone	Duration	
	0 hours	24 hours
LCB 870	9·682	7·929
RRIC 101	14·341	8·373

Table 5. *Effect of light pre-treatment on NPR (mg. CO_2 dm^{-2} h^{-1})*

Clone	Duration 0 hours	24 hours
IAN 710	10·374	9·064
RRIC 52	7·323	6·343

But when a 2 hour light or dark pre-treatment was given, the photosynthetic capacities were significantly higher than when measured immediately after detaching (Tables 6 and 7).

Table 6. *Effect of light/dark pre-treatment on NPR (mg. CO_2 dm^{-2} h^{-1}) — IAN 710.*

Pre-treatment	Duration (hours) 0	2	4	6
Light	13·296	15·453	12·942	13·211
Dark		15·888	14·627	14·348

Table 7. *Effect of light/dark pre-treatment on NPR (mg. CO_2 dm^{-2} h^{-1}) — RRIC 52*

Pre-treatment	Duration (hours) 0	2	4	6
Light	7·948	8·953	7·918	8·510
Dark		8·165	8·382	7·494

Photosynthetic capacities of leaves found in different whorls differed significantly in the two clones RRIM 600 and GT 1 tested. On both clones the whorl number two and three (when top most was taken as one) showed highest capacity (Table 8).

Table 8. *NPR (mg. CO_2 dm^{-2} h^{-1}) of leaves found in different whorls of a young rubber plant*

Clone	Whorl number 1	2	3	4	5
GT 1	12·646	14·697	14·602	11·625	6·849
RRIM 600	10·775	12·627	11·938	10·285	5·396

The NPR of clones RRIC 100, RRIC 103, RRIC 45, PB 86 and IAN 710 were significantly different at 0·1% level (Table 9).

Table 9. *NPR of some selected* Hevea *clones*

Clone	N.P.R. mg. CO_2 dm^{-2} h^{-1}
RRIC 100	7·515
RRIC 103	9·749
PB 86	11·503
IAN 710	10·537
RRIC 45	10·432

LSD = 0·669

DISCUSSION

During photosynthesis a concentration gradient exists between the CO_2 in the ambient air and the chloroplasts. The flux of CO_2 (net photosynthesis) is determined by the size of this gradient and by a series of resistances to the diffusion of CO_2.

The boundary layer resistance depends partly on the wind speed and partly on the geometry of the surface, particularly the size and shape of leaf (Zelitch, 1971). The average boundary layer is smaller for a narrow leaf than for a wide leaf and a relatively low wind speed is sufficient to diminish it. When the boundary layer is thick, the CO_2 diffusion is slow because CO_2 transfer through the boundary layer is much slower than transfer through the turbulent air above the boundary layer. This will result in lower NPR. Smaller leaf sections show optimum photosynthesis at relatively low air flow rates (at air flow rates the instrument is most sensitive for differential CO_2 measurements) in the chamber than when larger leaf sections are used.

When air flow rates in the leaf chambers are low larger leaf sections will not show optimum photosynthetic rates as CO_2 available could be limiting. Hence for accurate differential measurements leaf sections or entire leaves with leaf areas which show optimum NPR at flow rates around 500 ml/min should be used. Our experimental work suggests an ideal leaf section size of approximately 10 cm^2.

When NPR were measured using leaf sections and entire leaves (small mature leaves of approximately 10 cm^2) it was found that leaf sections can be obtained to study NPR without any drop in photosynthetic activity.

On a bright sunny day leaves detached at around 10-00 a.m., showed highest NPR. Photosynthetic capacities of leaves detached subsequently in the day declined slightly (Table 3). It could be that leaf photosynthetic activity shows a circadian rhythm.

With time, leaf tissue dehydration could occur due to transpiration resulting in decreasing photosynthetic capacity. Leaf tissue dehydration increases the internal diffusive resistances (Troughton, 1969). The large expanse of damp cell surfaces presented to the air inside a leaf makes for efficient absorption of CO_2 required for photosynthesis. High photosynthetic capacities around 1000 h could also be due to stomatal opening resulting from a higher leaf water content.

As early as 1868, T. B. Boussingault believed that accumulation of assimilates in an illuminated leaf could be responsible for a reduction in the net photosynthesis of that leaf. Several examples of an apparent inhibition of photosynthesis by end product accumulation have been described (Zelitch, 1971). This also could be responsible for the slight decline in photosynthetic rates observed in *Hevea* leaves detached later in the day. Hence it is essential to maintain similar physiological status of leaves to be used in comparative NPR determinations. This will help to reduce some of the variation which could occur apart from genetical differences in clones under study.

Experiments were conducted to decide on a suitable pre-treatment to be given to detached leaves prior to NPR measurements, in order to bring them into uniform physiological conditions. The methods tried were basically incubation of, detached leaves in dark, or light, for different periods of time.

Studies on photosynthetic capacities of leaves found in different whorls of a tree (young trees with five whorls were selected) reveals that a significant difference in photosynthetic capacities exist (Table 8). When the top most whorl was taken as one the leaves in the whorls two and three showed highest NPR. Hence it is necessary to select leaves of same age when comparing NPR of different clones. Samsuddin *et al* in their studies used the concept of leaf blade classes to characterize *Hevea brasiliensis* leaf age. In our studies we found leaves to show optimum photosynthetic capacities long after it has reached the maximum leaf blade class of 9. Hence, the number of days after emergence of a flush were monitored to characterize leaf age in days to sample leaves for comparative physiological studies.

The net photosynthetic rates of clones RRIC 100, RRIC 103, RRIC 45, PB 86 and IAN 710 were significantly different at 0·1% level.

The net photosynthetic rates observed did not necessarily correlate with yield, growth vigour in these studies (Table 10).

Table 10. *Mean yields, percentage of tappable trees after 6 years and NPR of some selected* Hevea *clones*

Clone	*Mean yield (g/t/t)	*% Tappable trees	NPR (mg. CO_2 dm^{-2} h^{-1})
RRIC 100	32·59	56·7	7·515
RRIC 103	30·06	72·0	9·749
PB 86	27·27	26·4	11·503
IAN 710	29·52	38·5	10·537

*Based on genotype environment studies

The light intensity in the field in a normal day is around 1500 — 1750 $\mu Em^{-2} s^{-1}$. Our NPR measurements were done at a light intensity of 800 $\mu Em^{-2} s^{-1}$. Further studies should be carried out at optimum light intensity before any definite conclusions are made.

In Samsuddin *et al's* work in 1979 comparing NPR of clones RRIM 600, TJ 1, PB 5/51 and F 351 in the laboratory, the differences were not statistically significant though the latex production differed considerably.

Even though the NPR per unit leaf area is low, the high yielding clones may have a greater leaf area, greater photosynthetically active duration of leaves, less dark respiratory and photorespiratory losses of carbon and efficient partitioning of assimilates. Also other variables inherent to the individual clones like crown geometry and crown volume could play a major role in determining field production. Hence it seems on initial studies that NPR alone will not give an idea about the productivity and growth vigour of *Hevea* clones.

ACKNOWLEDGEMENTS

The authors wish to thank Dr (Mrs) C. Samaranayake and Mr D. M. Fernando of RRISL for their assistance in the preparation of the manuscript. Our thanks are also due to Mr W. N. Wickramasinghe, Biometrician for analysis of results.

REFERENCES

AOKI, S., (1980). Measurement of photosynthetic activity using single cells and discs of tea leaves. *JARQ* **14**, 36 — 40.

CHANDLER, R. F., JR., (1969). New horizons for ancient crop. *11th Int. Bot. congr. Symp. World Food Supply.*

CURTIS, P. E., OGREN, W. L., AND HAGEMAN, R. H. (1969). Varietial effects in soyabean photosynthesis and photorespiration. *Crop. Sci.* **9**, 323 — 327.

HESKETCH, J. D. (1963). Limitations to photosynthesis responsible for differences among species. *Crop. Sci.* **3**, 493 — 496.

HESKETCH, J. D. AND MOSS, D. N. (1963). Variation in the response of photosynthesis to light. *Crop. Sci.* **3**, 107 — 110.

HOLMGREN, P., JARVIS, P. G., AND JARVIS, M. S. (1965). Resistances to carbon dioxide and water vapour transfer in leaves of different plant species. *Physiol. Plant.* **18**, 557 — 573.

JAYASEKERA, N. E. M., KARUNASEKERA, K. A. B. AND RUPATUNGE, K. W. (1983). Genotype-environment interaction studies. *A. Rev. Rubb. Res. Inst. Sri Lanka 1983*, **36 — 38**.

MENZ, K. M. MOSS, D. N., AND BRUN, W. A. (1969). Screening for photosynthetic efficiency. *Crop. Sci.* **9**, 692 — 694.

SAMSUDDIN, Z., AND IMPENS, I. (1979). Photosynthetic rates and diffusion resistances of seven *Hevea brasiliensis* Muell. Arg. clones Biol. *Planta* **21**, 154 — 156.

SAMSUDDIN, Z., AND IMPENS, I. (1979). Relationship between leaf age and some carbon dioxide exchange characteristics of four *Hevea brasiliensis* Muell. Arg. clones. *Photosynthetica* **13**, 208 — 210.

SAMSUDDIN, Z., AND IMPENS, I. (1979). The development of photosynthetic rate with leaf age in *Hevea brasiliensis* Muell. Arg. clonal seedlings. *Photosynthetica* **13**, 267 — 270.

SAMSUDDIN, Z., KHIR, M. A. R., AND IMPENS, I. (1978). The development of leaf blade class concept for the characterisation of *Hevea brasiliensis* Muell. Arg. leaf age. *J. Rubb. Res. Inst. Malaysia* **26**, 1 — 5.

TREGUNNA, B. (1966). Flavin mononucleotide control of glycolic acid oxidase and photorespiration in corn leaves. *Science* **151**, 1239 — 1241.

TROUGHTON, J. H. (1969). Plant water status and carbon dioxide exchange of cotton leaves. *Aust. J. Biol. Sci.* **22**, 289 — 312.

ZELITCH, I. (1971). *Photosynthesis, Photorespiration, and Plant Productivity*, New York : Academic Press, Inc.

DISCUSSION

Q — SAMSUDDIN : In your slide you showed the net photosynthetic rate that you have observed was lower in bigger areas. In another slide it showed net photosynthetic rate of an entire leaf was equal to a leaf section. As an entire leaf area is certainly bigger than a segment, how do you explain this phenomena.

A — A. NUGAWELA, RRI, Sri Lanka : Actually in that study I used an entire leaf which had the same leaf area of a leaf section I used. That is to say that I used small leaves which you find at the top part of a leaf whorl.

Q — SAMSUDDIN : This is a comment. I noticed the flow rate of air into your chamber was only about 30 cubic dm for an hour that is 0·5. l per minute

A — A. NUGAWELA, RRI, Sri Lanka : I used 0·5 l per minute.

Q — SAMSUDDIN : Observed lower net photosynthetic rate in a bigger segment area in your study may be due to the limiting CO_2 concentration because the air was not replenished fast enough. How do you standardize your leaf age in your study.

A — A. NUGAWELA, RRI, Sri Lanka : I used the number of days after emergence of a leaf for this.

Q — SAMSUDDIN : Can you tag your leaves in the field.

A — A. NUGAWELA, RRI, Sri Lanka : Yes.

BIOMASS PRODUCTION AND RUBBER YIELD WITH REFERENCE TO EXPLOITATION IN *HEVEA BRASILIENSIS*

BY

M. J. GEORGE, K. V. SATHEESAN, A. S. RAGHAVENDRA AND M. R. SETHURAJ

(*Plant Physiology Division, Rubber Research Institute of India, Kottayam*)

ABSTRACT

The productivity of PR 107 rubber trees (in terms of dry matter increment and rubber yield) was examined at eight different exploitation systems over 3 years. Untapped Hevea brasiliensis *trees had high rates of biomass production reaching upto 50 t* ha^{-1} y^{-1}.

The biomass production decreased while the harvest index (ratio of dry rubber yield to the total dry matter of trees) increased with increasing intensity of tapping. The extent of decrease in dry matter increment due to tapping (factor ' k ') was the least in trees tapped once every week.

When ¼S cuts were stimulated to maintain the yield levels of corresponding ½S cuts, the harvest index and yield were comparable. But the slightly higher values of factor ' k ' with ¼S cuts, under stimulation, than those of ½S cuts, suggested that stimulation by Ethephon involved considerable reduction in biomass.

INTRODUCTION

The yield of rubber is determined by four major components viz. the initial flow rate, length of tapping cut, dry rubber content and the plugging index (Sethuraj, 1981). The length of tapping cut, or the girth is highly variable among and within clones (Paardekooper and Samosorn, 1969 ; Sethuraj and George, 1980). As the length of cut is a component of yield, optimal growth of the tree should be ensured to achieve high sustained yields. It is known that the exploitation of the tree by tapping affects the vigour of the tree. The annual biomass increment in a tapped tree is substantially less than that of an untapped tree (Dijkman, 1951). Such loss in biomass production, due to tapping cannot be competely accounted for by the rubber yields, even if the higher energy content of rubber is taken into consideration (Templeton, 1969). Simmonds (1982) has since suggested that the energy required for rubber production might be much more than that contained in rubber itself. Sethuraj (1982), during his analysis and simulation of yield components in *Hevea* indicated that the extent of such loss in biomass production, termed factor ' k ', is an important aspect of yield potential.

In this Institute, the pattern of biomass production and rubber yield in *Hevea* at different exploitation levels, particularly in RRIM 600 and PR 107 have been studied. Our earlier observations on RRIM 600 were presented elsewhere (George *et al.*, 1982). The effect of intensity of exploitation on biomass production, harvest index and yield is analysed in this communication.

MATERIALS AND METHODS

The experiment was initiated in 1981 at the Central Experiment Station, Chethackal, with clone PR 107 (planted in 1968; tapping commenced in 1976). Eightyone trees were selected and randomly allotted to the following nine treatments. A density of 310 plants per hectare was assumed.

1. No tapping
2. ½S d/1 6d/7
3. ½S d/2 6d/7
4. ½S d/3 6d/7
5. ½S d/7
6. ½S d/1 6d/7 ET 5%
7. ½S d/2 6d/7 ET 5%
8. ½S d/3 6d/7 ET 5%
9. ½S d/7 ET 5%

The trees were under ½S d/2 6d/7 system of tapping before these experiments. The tapping was either discontinued or the existing cuts/the frequency of tapping were adjusted according to the above treatments. The stimulant *i.e* 5% (w/v) Ethephon was applied by bark application, monthly. The trees were rainguarded to facilitate tapping all through the year.

Yield recording was done on all tapping days by cup coagulation method. Dry matter increment was calculated from the girth of stem by using the formula of Shorrocks *et al* (1965). Harvest index was calculated by the formula :

$$\frac{(Y \times 2 \cdot 5)}{(Y \times 2 \cdot 5) + G}$$

Where Y is the rubber yield and G, the dry matter increment.

The factor 'k' was calculated following the formula :

$$\frac{W_{ut} - [W_t + (Y \times 2 \cdot 5)]}{W_{ut}}$$

Where W_{ut} is the dry matter increment of the untapped tree and W_t that of the tapped tree.

RESULTS AND DISCUSSION

The rates of biomass production in untapped trees which was 38 and 27 t ha $^{-1}$ Y $^{-1}$ in 1981 – 82 and 1982 – 83, respectively, went upto 50 t ha $^{-1}$ Y $^{-1}$ in 1983 – 84. The average production for all the 3 years was 38·3 t ha $^{-1}$ Y $^{-1}$. The low level of biomass production in 1982 – 83 might be due to the prevailing drought in that period. The differences in biomass production among various exploitation systems were not statistically significant during the first 2 years *i.e* 1981 – 82 and 1982 – 83. The initial variation in the girth of trees in between replicates of different treatments could be the reason. However, the cumulative effect of these treatments was reflected by the third year (1983 – 84), as evidenced by the statistically significant variation.

Biomass production decreased with increasing frequency of tapping with or without stimulation (Table 1). Such decrease due to exploitation was drastic in daily tapped trees. There was a marked fall in dry matter production in all the treatments during 1982 – 83 and productivity increased during 1983 – 84 in all treatments, except in daily tapped trees. Among the tapped ones, the trees with ¼S d/7 with Ethephon had the highest rates of biomass increase during the entire period of experimentation. The biomass production as well as dry rubber yield from trees was highest in 1983-84 and the least in 1982 – 83. The reasons might be that there was a severe drought spell in 1982 – 83 while the rainfall was moderate and well distributed in 1983 – 84.

Table 1. *Biomass production (t ha $^{-1}$ y $^{-1}$), harvest index and factor 'k' in relation to exploitation system during 1983 – 84.*

Exploitation systems	Biomass production	Harvest index	Factor 'k'
No tapping	49·9	—	—
½S d/1 6d/7	20·8	0·28	0·425
½S d/2 6d/7	25·9	0·15	0·387
½S d/3 6d/7	27·5	0·14	0·362
½S d/7	29·0	0·06	0·383
¼S d/1 6d/7 ET 5%	20·4	0·28	0·430
¼S d/2 6d/7 ET 5%	23·1	0·19	0·426
¼S d/3 6d/7 ET 5%	24·8	0·14	0·425
¼S d/7 ET 5%	31·2	0·06	0·333
C. D. (P = 0·05)	12·5	0·12	0 092

The rates of biomass production in *Hevea* in untapped trees were in the higher range reported on tropical rain forests (Hall, 1976). Therefore, with marked capacities of biomass production and additional yields of a commercially important product like rubber, *Hevea brasiliensis* can be a suitable species for agro-social forestry, an agronomic practice which gained global attention (Nair, 1980).

Exploitation is known to retard drastically the girthing of the tree and the biomass production (Dijkman, 1951 ; Templeton, 1969). Table 1 establishes that increased frequency of tapping irrespective of stimulation or length of tapping cut, markedly decreases biomass production. A steep decrease in biomass production even in trees with quarter spiral cut, suggests that it is the extent of latex extracted out, but not the length of cut, which affects the vigour of the tree.

The differences in yield with varying exploitation systems were as expected. The maximum yield was obtained with d/1 systems, even in the third year of tapping (Table 2). Application of Ethephon on a quarter spiral system resulted in good yields, almost equalling those corresponding to a half spiral system. A consistent increase in the yield of stimulated trees during all the 3 years suggested that the response to stimulation was steady in trees with quarter spirals (Table 2).

Table 2. *Dry rubber yield* ($t\ ha^{-1}\ y^{-1}$) *in relation to exploitation system during 1981–84*

Exploitation systems	1981 – 82	1982 – 83	1983 – 84
No tapping	—	—	—
½S d/1 6d/7	2·53	3·02	3·15
½S d/2 6d/7	1·81	2·20	1·87
½S d/3 6d/7	1·69	1·72	1·73
½S d/7	0·69	0·79	0·72
¼S d/1 6d/7 ET 5%	2·36	3·03	3·22
¼S d/2 6d/7 ET 5%	1·45	1·92	2·22
¼S d/3 6d/7 ET 5%	1·04	1·50	1·56
¼S d/7 ET 5%	0·47	0·70	0·84
C. D. (P = 0·05)	0·31	0·48	0·31

The different exploitation systems altered not only the rubber yield and dry matter production but also the harvest index (Table 1). Maximum values of harvest index on d/1 systems and minimal harvest index values at d/7 tappings suggested that at higher tapping intensities, assimilate partitioning towards rubber biosynthesis was also enhanced. Despite shortening the length of the cut, harvest index was not much lowered in quarter spiral systems, due to Ethephon stimulation of latex flow.

The loss in biomass due to tapping (Table 1) was pronounced in high intensity systems and this factor was very low on a ¼S d/7 system, irrespective of stimulation. A steep increase in the biomass loss was evident in daily tapped trees. The extent of reduction in biomass could be expressed by factor ' k ' as suggested by Sethuraj (1982). But stimulation treatments resulted in higher 'k' values indicating a direct effect of stimulation on biomass loss.

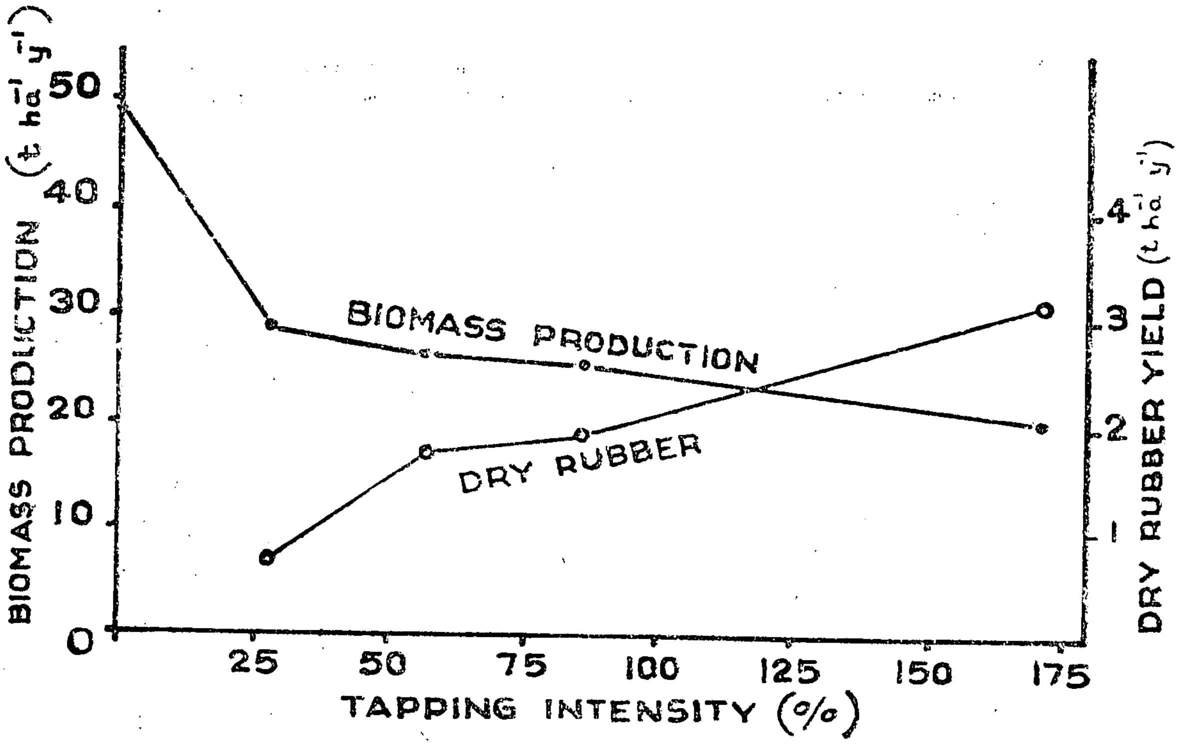


Fig. 1. Biomass production and dry rubber yield of PR 107 in relation to tapping intensity. The trees were tapped once in 1, 2, 3 or 7 days on a half spiral cut, as indicated in Materials and Methods.

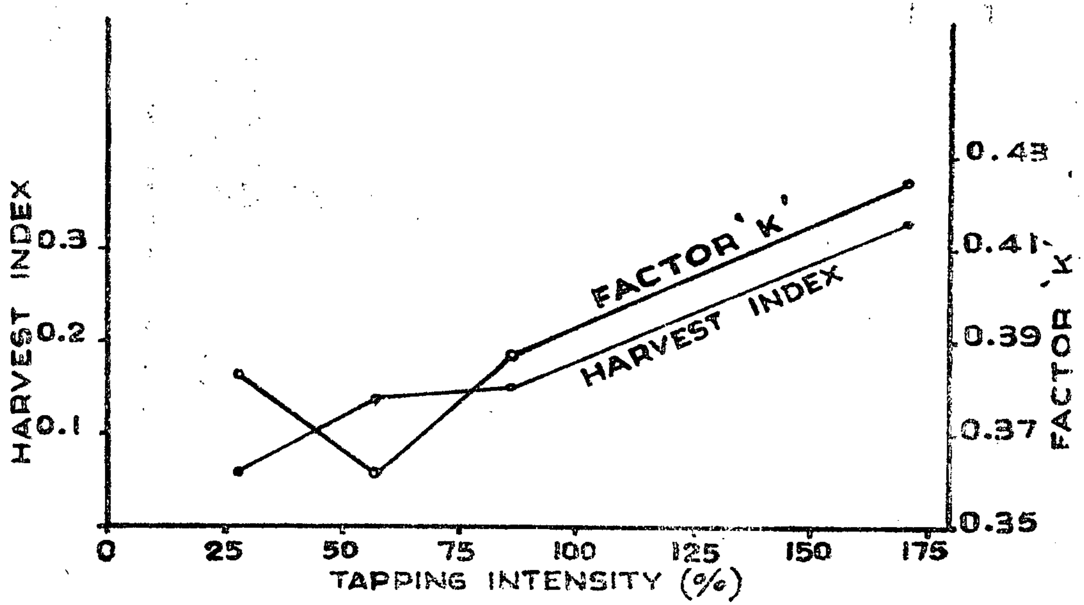


Fig. 2. Harvest index and factor 'k' of PR 107 in relation to tapping intensity. The details are as in Fig. 1.

It can be concluded from our observations that an increase in tapping intensity decreases biomass production (Fig. 1) but raises the harvest index and factor 'k' (Fig. 2). The depressing effect of tapping on biomass production is usually reduced by shortening the cut. But when ¼S cuts were stimulated to maintain the yield levels of corresponding ½S cuts, biomass loss was slightly higher. This is evident from higher values of 'k' factor in treatments with ¼S cuts and stimulation, in spite of the fact that harvest index and yield were comparable with corresponding ½S treatments. The reason for the loss of biomass as a result of latex extraction, not accountable by the yield of latex obtained, is yet to be elucidated. One possibility is the higher respiration induced by tapping and stimulation with Ethephon.

ACKNOWLEDGEMENTS

The authors acknowledge the cooperation of the Senior Superintendent, Central Experiment Station, Chethackal, and the help from field/laboratory staff of the Plant Physiology and Exploitation Division.

REFERENCES

DIJKMAN, M. J. (1951). *Hevea : Thirty years of Research in the Far East.* University of Miami Press, Florida.

GEORGE, M. J., SATHEESAN, K. V., AND SETHURAJ, M. R. (1982). Effect of exploitation methods on biomass production, harvest index and yield in *Hevea brasiliensis. PLACROSYM - V, Proceedings of the Vth annual symposium on plantation crops,* (in press).

HALL, D. O. (1976). Photobiological energy conversion. *FEBS Letters.* **64,** 6 - 16.

MILFORD, G. F. J., PAARDEKOOPER, E. C., AND HO, C. Y. (1969). Latex vessel plugging, its importance to yield and clonal behaviour. *J. Rubb. Res. Inst. Malaya* **21,** 274 – 282.

NAIR, P. K. R. (1980). *Agroforestry species. A crop sheets manual.* International council for Research in Agro, forestry, Nairobi, pp. 336.

PAARDEKOOPER, E. C., AND SAMOSORN, S. (1969). Clonal variation in latex flow pattern. *J. Rubb. Res. Inst. Malaya.* **21,** 264 – 273.

SETHURAJ, M. R., AND GEORGE, M. J. (1980). *Tapping. Handbook of Natural Rubber Production in India.* (Ed. P. N. R. Pillay), *Rubb. Res. Inst. of India. Kottayam,* 209 – 234.

SETHURAJ, M. R. (1981). Yield components in *Hevea brasiliensis* theoretical consideration. *Plant, Cell and Environment.* **4,** 81 – 83.

SETHURAJ, M. R. (1982). Proposals for international collaboration in the investigations on physiological aspects of yield in *Hevea brasiliensis. Inter. Rubb. Res. and Dev. Board Meeting, Malaysia.*

SHORROCKS, V. M., TEMPLETON, J. K. AND IYER, G. C. (1965). Mineral nutrition, growth and nutrient cycle of *Hevea brasiliensis.* III The relationship between girth and shoot dry weight. *J. Rubb. Res. Inst. Malaya* **19**, 85 – 92.

SIMMONDS, N. W. (1982). Some ideas on Botanical research on rubber. *Trop. Agr.* **59**, 2 – 8.

TEMPLETON, J. K. (1969). Partitioning of assimilates. *J. Rubb. Res. Inst. Malaya* **21**, 259 – 263.

DISCUSSION

Q — BARLOW, Australia : Explain the means of measuring of biomass and your definition of biomass.

A — M. J., GEORGE, India : It was based on annual girth recording. The girth of a tree was recorded 15 inches high and from that annual biomass increment was calculated by following the formula of Shorrocks 1965.

Q — SAMSUDDIN, RRIM : In your calculation of the biomass do you estimate dry matter attributed by the leaf fall throughout the year.

A — M. J. GEORGE, India : As mentioned, biomass was calculated on the formula by Shorrocks 1965. Definition of biomass is dry matter increment or dry matter production.

RESPONSES OF *HEVEA* CULTIVARS TO MILD STIMULATION

By

C. K. LEE, ISMAIL HASHIM AND P. D. ABRAHAM
(*Rubber Research Institute, Malaysia*)

ABSTRACT

Some cultivars tapped on panel BO - 1 and BO - 2 respond moderately well to stimulation with 2·5% and 5% Ethephon. In other cultivars the responses were poor. In trees tapped on panels BO - 2 and B1 - 1, positive responses, to stimulation with 2·5% and 5% Ethephon were observed in various cultivars. In older trees tapped on panels HO - 1 and HO - 2, good yields can be obtained with upward tapping and mild stimulation. Trees under mild stimulation had a relatively good girth increment, moderately low percentage of panel dryness and a good DRC in the latex.

INTRODUCTION

In late 1960's and in 1970's when Ethephon was first used as a stimulant to prolong latex flow, 10% concentration of the stimulant was commonly used. The responses had been good on most cultivars. However, in many instances, there was a rapid decline in the responses, and in some cases stimulated trees yielded less than the unstimulated trees after 3 years. In view of this, the Rubber Research Institute of Malaysia began to examine the possibility of using lower concentrations of Ethephon. Experiments on *Hevea* trees of various age groups were set up in different states in the country. Tapping systems with various lengths of cut were included in the experiments and some of the data obtained are summarised in this paper.

MATERIALS AND METHODS

The experiments were carried out in the states of Kedah, Selangor and Johore. In some of the experiments, stimulation began on young trees on the first year of tapping on panel BO - 1 and continued over various periods of time. In the other trials stimulation began on panels BO - 2, B1 - 1 or HO - 1. Stimulation is carried out on either scraped bark below the cut, on the groove or on the lace. The randomised block designs were used, and various blocks were allotted to different treatments based on the average yield of 10 per-treatments tappings. Details of the experiments are given in Table 1. Tapping began at 0700 h and latex collection began at 1200 h. Yield obtained after 1200 h (noon) were collected as late drip in the next tapping. Yield recording was carried out on each tapping and DRC determination was done on alternate tapping. A census on panel dryness was carried out quarterly and the length of the tapping panel measured every year in most of the trials. The length of dry panel over the total panel length gives the percentage dryness in each treatment. A quarterly measurement of the girth increment was also carried out for all the trees in some of the experiments.

Table 1. *Details of experiments*

Experiment Number	Cultivar	Site	Year of Planting	Date expt. commenced	Tapping panel at commencement	Design	No. of trees/ treatment
BE 691·1	PR 255	Kedah	1966	May 1974	BO - 1	2 blocks	44
BE 689·1	RRIM 600	Kedah	1963	April 1972	BO - 1	2 blocks	48
BE 689·2	RRIM 623	Kedah	1964	April 1972	BO - 1	2 blocks	48
BE 689·4	PBIG/GG1	Kedah	1965	June 1972	BO - 1	2 blocks	48
BE 688·23	GT 1	Kedah	1971	January 1978	BO - 1	4 blocks	72
BE 303·2	RRIM 623	Johore	1965/6	November 1979	BO - 2	2 blocks	60
BE 699·12	GT 1	Selangor	1961	September 1978	BO - 1, HO - 1	3 blocks	25
BE 689·13	PB 5/51	Kedah	1960	July 1977	Bl - 1	2 blocks	64
BE 689·14	RRIM 623	Kedah	1960	July 1977	Bl - 1	2 blocks	60
BE 689·15	RRIM 605	Kedah	1960	August 1977	Bl - 1	2 blocks	50
BE 303·4	RRIM 605	Johore	1962/3	May 1980	Bl - 1, HO - 1, HO - 2	2 blocks	30
BE 715·8	PB 5/51	Johore	1958	May 1976	Bl - 1, HO - 1, HO - 2 HO - 3	2 blocks	160
BE 692·61	GT 1	Selangor	1976	July 1976	Bl - 1, HO - 1, HO - 2 HO - 3	2 blocks	60
BE 105·1	GT 1	Kedah	1958	June 1981	Bl - 1	3 tasks	750 — 1300

Rubber yield

Panels BO - 1 and BO - 2

Clone PR 255 responds moderately well to stimulation with 2·5% and 5% Ethephon (Table 2). There was no consistent difference in the responses to stimulation with 2·5% and 5% Ethephon. Among all the treatments, 1/2S d/2 ET 2·5% Ba2m gave the highest yield with 164% compared with 1/2S d/2 control over a period of 9 years on panels BO-1 and BO-2. This was followed by 1/2S d/2 ET 5% Ba2m with 154%. Good responses were also obtained with 1/4S d/2 ET 2·5% Ba2m, 1/4S d/2 ET 5% Ba2m and 1/4S d/2 (t,t) ET 2·5% Lam, 1/4S d/2 (t,t) ET 2·5% Ba2m which yielded 134%, 141%, 147% and 152% respectively over the 9 – year period. Fig. 1 shows the yield trend of 1/2S d/2 ET 2·5% Ba2m, 1/4S d/2 ET 2·5% Ba2m and 1/4S d/2 (t,t) ET 2·5% Ba2m. In the first 5 years of stimulation, there was no consistent decline in the yield of the stimulated systems. However, after the sixth year, the relative yield of all the stimulated systems began to decline, the decline was more rapid in 1/2S d/2 ET 2·5% Ba2m than in the 1/4 cut treatments.

Table 2. *PR 255, panels BO - 1, BO - 2, Bl - 1 cumulative yield in kg ha - 1 for 9 years*

Tapping Cut	Treatment	d/2	d/3	d/2 (t,t)
1/2S	Control	9570 (100)	8488 (89)	—
	ET 2·5% Ba2m	15741 (164)	12938 (135)	—
	ET 5% Ba2m	14763 (154)	12273 (128)	—
	ET 2·5% Lam	12804 (134)	10997 (115)	—
	ET 5% Lam	12728 (135)	12388 (129)	—
1/4S	Control	6920 (72)	—	7669 (80)
	ET 2·5% Ba2m	12789 (134)	—	14063 (147)
	ET 5% Ba2m	13519 (141)	—	12509 (131)
	ET 2·5% Lam	7919 (83)	—	14515 (152)
	ET 5% Lam	11736 (123)	—	12279 (128)

Assumed tappable stand/hectare : 296 trees
Figures within brackets denote percentage values of 1/2S d/2 control.
Actual frequency : 6d/7

With PBIG seedlings, there was also a moderately good response to stimulation with 2·5% and 5% Ethephon (Table 3). During the first 10 years of tapping, 1/2S d/3 ET 2·5% Ba2m gave the highest yield with 165% compared with 1/2S d/3 control. Moderately good responses were also obtained in the 1/4S cut systems. In the 1/2S systems, stimulation with 5% did not give higher responses compared with stimulation with 2·5% Ethephon. In the 1/4S systems 5% Ethephon resulted in slightly higher responses. Fig. 2 shows the yield trend over the 10-year period for 1/2S d/3 ET 2·5% Ba2m, and 1/4S d/3 ET 2·5% Ba2m. With both systems, there was an increase in the responses to stimulation in the first 3 years. Subsequently there was some decline in the response to stimulation but the decline was gradual.

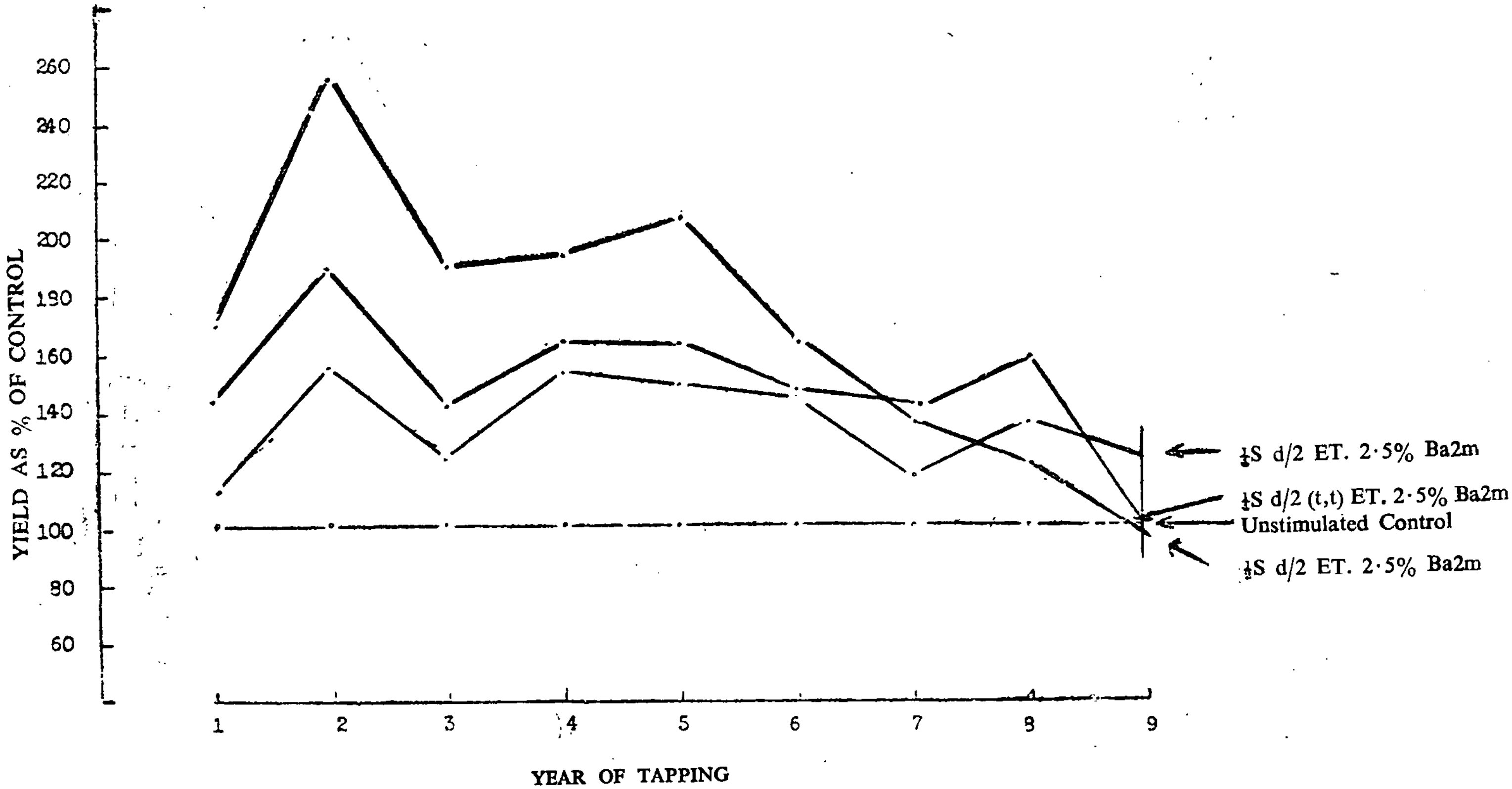


Fig. 1. Relative yield trend PR 255, panels BO-1 and BO-2

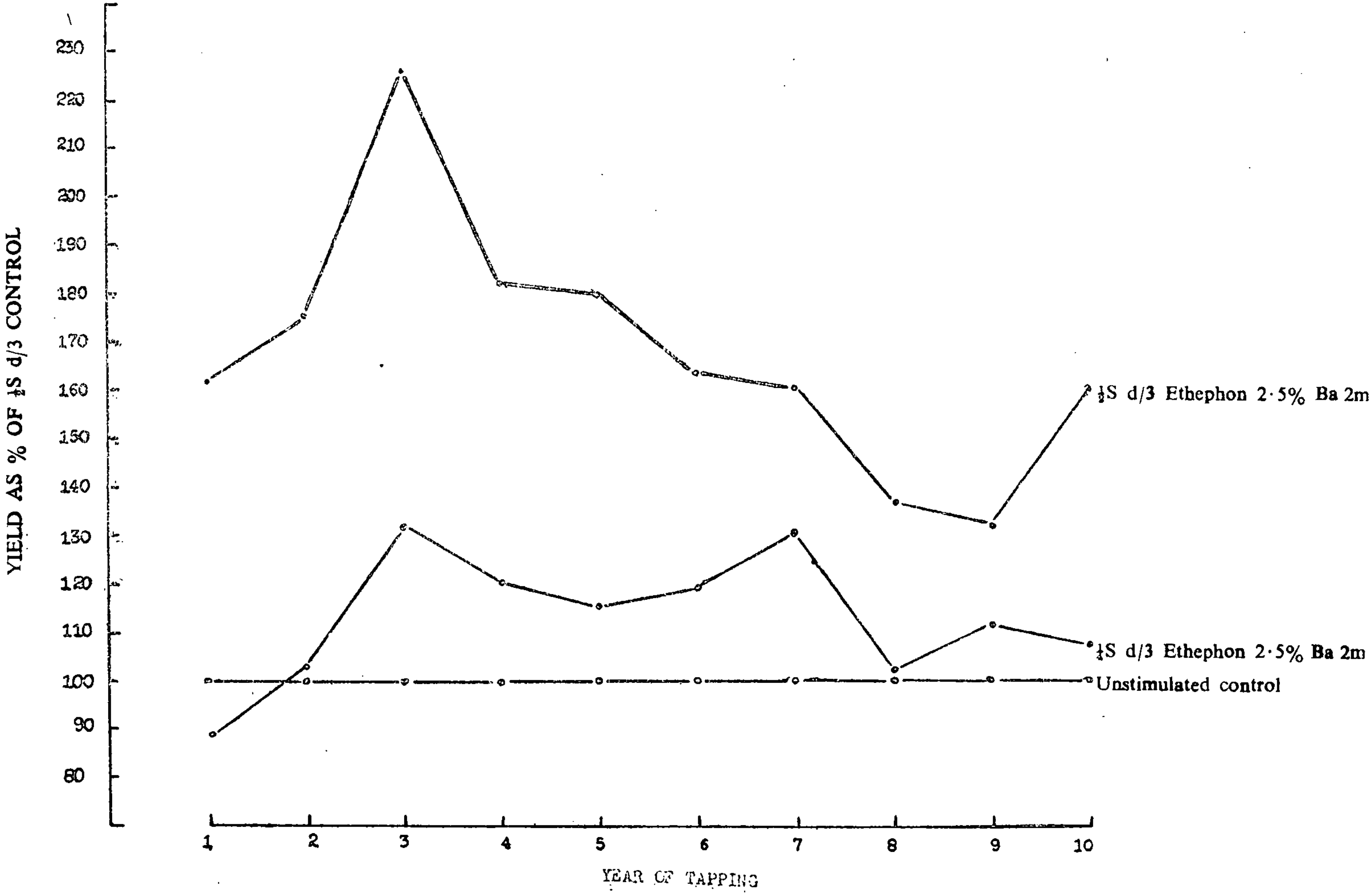


Fig. 2. Relative yield trend in first 10 years of tapping PBIG seedlings

Table 3. *PBIG seedlings cumulative yield in kg/ha-1 in the first 10 years of tapping*

Tapping cut	Treatment	d/2	d/3
1/2S	Control		12257 (100)
	ET 2·5% Ba2m		20274 (165)
	ET 5·0% Ba2m		17496 (143)
	ET 2·5% Lam		16942 (138)
	ET 5·0% Lam		17062 (139)
1/4S	Control	12189 (99)	9866 (80)
	ET 2 2% Ba2m	18012 (147)	13867 (113)
	ET 5 0% Ba2m	18301 (149)	17514 (143)
	ET 2·5% Lam	16255 (133)	13013 (106)
	ET 5 0% Lam	17007 (139)	14764 (120)

Assumed tappable stand/hectare : 296 trees
Figures within brackets denote percentage values of 1/2S d/3 control.
Actual frequency : 6d/7

RRIM 600 and RRIM 623 panels BO-1 and BO - 2 the responses to stimulation were generally poor (Table 4). In most of the cases the stimulated systems yielded less than 1/2S d/2 control during the 10-year period. This was mainly due to the relatively high yield of the control system on panel BO - 2. In GT 1 tapped on 1/4S d/3 (t,t) over a period of 3 years, stimulation with 2 5%, 5% and 10% Ethephon resulted in yield increments of 35%, 44% and 54%, respectively, compared with the unstimulated control. When the tapping system was changed to 1/2S d/3, yield increase due to stimulation was 21%, 22% and 24%, respectively, for the three levels of stimulant over a period of 3 years (Table 5). Fig. 3 shows that 1/4S d/2 (t,t) with mild stimulation and 1/2S d/3 with the same levels of stimulation did not result in drastic yield decline during the experimental periods, and stimulation with 2 5% Ethephon gave approximately the same yield as stimulation with the 5% stimulant in the last 3 years.

Panels BO - 2 and B1 - 1

In an experiment on RRIM 623 tapped on panel BO - 2 and B1 - 1 over a period of 4 years, 1/4S d/2 (t,t) ET 5% Lam and 1/4S d/2 (t,t) ET 2·5% Lam yielded 116% and 91%, respectively, compared with 1/2S d/2. In 1/4S d/2 (t,t) ET 10% Lam the yield was 131% over the same period of time (Table 6). In clone GT 1, 1/4S d/2 (t,t) ET 5% Lam yielded 106% and 1/4S d/2 (t,t) ET 2 5% Lam yielded 102% compared with 1/2S d/2 control over a period of 5 years. In 1/2S d/2 ET 2·5% Lam and 1/2S d/2 ET 5% Lam, the yield was 103% and 126%, respectively, over the same period of time (Table 7).

The responses of clones PB 5/51, RRIM 623 and RRIM 600 tapped on panel B1 - 1 to stimulation with 2·5%, 5% and 10% Ethephon over a period of 5 years (Table 8). The tapping system was 1/2S d/3. In PB 5/51, stimulation with 2·5% Ethephon yielded 132%, whereas stimulation with the 5% and 10% stimulant yielded 140% and 138% respectively, over the same period. In RRIM 605 the yield was 129%, 139% and 169%,

Table 4. *RRIM 600 and RRIM 623, panels BO - 1 and BO - 2 cumulative yield in kg ha-1 for 10 years*

Tapping cut	Treatment	d/2 RRIM 600	d/2 RRIM 623	d/3 RRIM 600	d/3 RRIM 623
1/2S	Control	20237 (100)	17345 (100)	—	—
	ET 2·5% Ba2m	—	—	—	—
	ET 5·0% Ba2m	20099 (99)	—	19226 (95)	15532 (90)
	ET 2·5% Lam	—	17472 (101)	—	—
	ET 5·0% Lam	17345 (86)	15994 (92)	19646 (97)	15426 (90)
1/4S	Control	—	8359 (48)	—	—
	ET 2·5% Ba2m	19874 (98)	—	—	—
	ET 5·0% Ba2m	21477 (106)	—	—	—
	ET 2·5% Lam	19050 (94)	12973 (75)	—	—
	ET 5·0% Lam	18137 (90)	15290 (88)	—	—

Assumed tappable stand/hectare : 296 trees.
Figures within brackets denote percentage values of 1/2S d/2 control.
Actual frequency : 6d/7

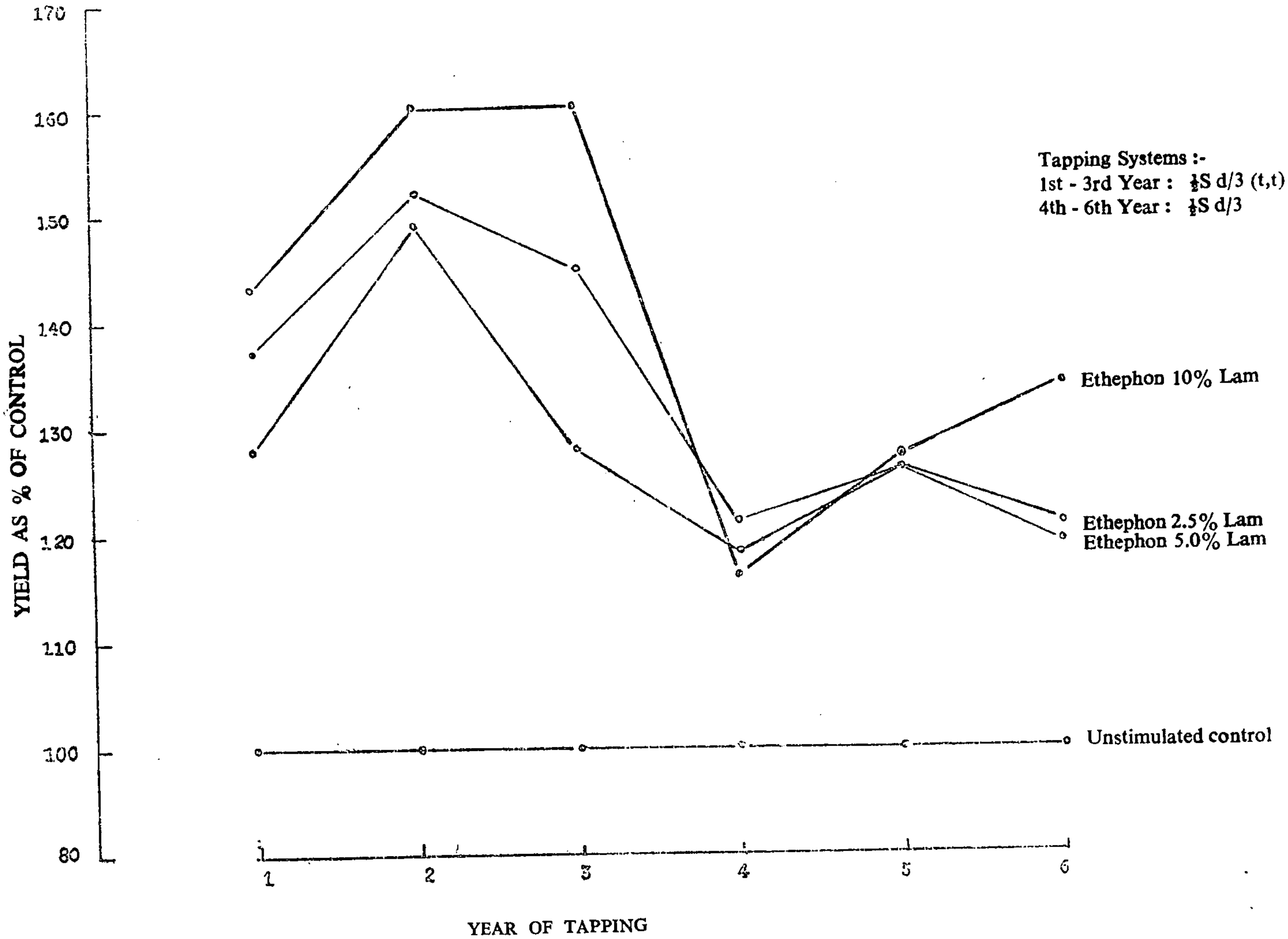


Fig. 3. Relative yield trend GT. 1, panel BO-1

Table 5. *GT 1, panel BO - 1*

Treatment	Total yield 1st - 3rd yr. kg/ha-1	Treatment	Total yield 4th - 6th yr. kg/ha-1
1/4S d/3 (t,t) Control	1638 (100)	1/2S d/3 Control	3528 (100)
1/4S d/3 (t,t) ET 10% Lam	2520 (154)	1/2S d/3 ET 10% Lam	4370 (124)
1/4S d/3 (t,t) ET 5% Lam	2362 (144)	1/2S d/3 ET 5% Lam	4305 (122)
1/4S d/3 (t,t) ET 2·5% Lam	2209 (135)	1/2S d/2 ET 2·5% Lam	4282 (121)

Tapping system for the first 3 years was 1/4S d/3 (t,t)
Tapping system for the last 3 years was 1/2S d/3
Figures within brackets denote percentage values of 1/4S d/3 (t,t) control and 1/2S d/3 control.
Assumed tappable stand/hectare : 296 trees
Actual frequency : 6d/7

Table 6. *RRIM 623, panels BO - 2 and BI - 1 cumulative yield in kg/ha - 1 for 4 years*

Treatment	Yield	% increase
1/2S d/2 Control	7255	(100)
1/4S d/2 (t,t) ET 10% Lam	9484	(131)
1/4S d/2 (t,t) ET 5% Lam	8432	(116)
1/4S d/2 (t,t) ET 2·5% Lam	6606	(91)

Assumed tappable stand/hectare : 296 trees.
Actual frequency : 6d/7
Figures within brackets denote percentage values of 1/2S d/2 control.

Table 7. *GT 1 panels BO - 2 and BI - 1 cumulative yield in kg/ha-1 for 5 years*

Treatment	% increase
1/2S d/2 Control	(100)
1/2S d/2 ET 2·5% Lam	(103)
1/2S d/2 ET 5% Lam	(126)
1/4S d/2 (t,t) ET 2·5% Lam	(102)
1/4S d/2 (t,t) ET 5% Lam	(106)

Assumed tappable stand/hectare : 296 trees
Figures within brackets denote percentage values of 1/2S d/2 control.
Actual frequency : 6d/7

respectively, for trees stimulated with 2·5%, 5% and 10% Ethephon. In RRIM 623 the yield was 122%, 144% and 139%, respectively, for the three levels of stimulant. Fig. 4 shows the yield trend in the three clones with all the three levels of stimulant. In PB 5/51 there was a gradual decline in the relative yield in all the stimulated systems in the first 4 years. However, when the tapping cut was changed over to the high panel on the fifth year, there was a resurgence in yield during the year for all the stimulated systems.

Table 8. *PB 5/51, RRIM 605 and RRIM 623, panel Bl - 1 cumulative yield for 5 years*

Treatment	PB 5/51* kg/ha-1 %	RRIM 605 kg/ha-1 %	RRIM 623 kg/ha-1 %
1/2S d/3 Control	6132 (100)	6827 (100)	7937 (100)
1/2S d/3 ET 10% Lam	8468 (138)	11521 (169)	11072 (139)
1/2S d/3 ET 5% Lam	8591 (140)	9490 (139)	11453 (144)
1/2S d/3 ET 2·5% Lam	8068 (132)	8787 (129)	9675 (122)

Assumed tappable stand/hectare : 296 trees
Figures within brackets denote percentage values of 1/2S d/3 control.
Actual frequency : 6d/7
*The fifth year was tapped on HO-1

In RRIM 605, there was a consistent decline in the response to all the three levels of stimulation during the experimental period and higher Ethephon concentration gave a higher response, particularly in the first 3 years of the experiment.

In RRIM 623, stimulation with 5% Ethephon gave a slightly lower yield compared with stimulation with the 10% stimulant in the first 2 years. However, after the second year, trees stimulated with the 5% stimulant gave a higher yield. In this clone the response to stimulation with 2·5% Ethephon was significantly lower than the responses to the other two levels of stimulation in the first 4 years. In the fifth year of tapping, trees stimulated with 5% Ethephon gave the highest yield while stimulation with 10% and 2·5% Ethephon gave comparable responses.

Panels HO - 1 and HO - 2

In the trial on RRIM 605 tapped on panels B1-1, HO-1 and HO - 2-1/4S ↑ d/2 ET 5% yielded 203% over a period of 3 years compared with 1/2S d/2 control. Trees tapped on the same system and stimulated with 2·5% Ethephon yielded 173% during the same period (Table 9).

In a trial on PB 5/51 panels B1 - 2 and HO - 2 over a period of 4 years, 1/4S ↑ d/2 ET 5% Lam yielded 222% and 1/8S ↑ d/2 ET 5% Lam yielded 192%. Trees that were tapped on 1/2S d/2 ET 5% Gam for 2 years and 1/2S ↑ d/2 ET 5% for 1 year yielded 227%. This is shown in Table 10.

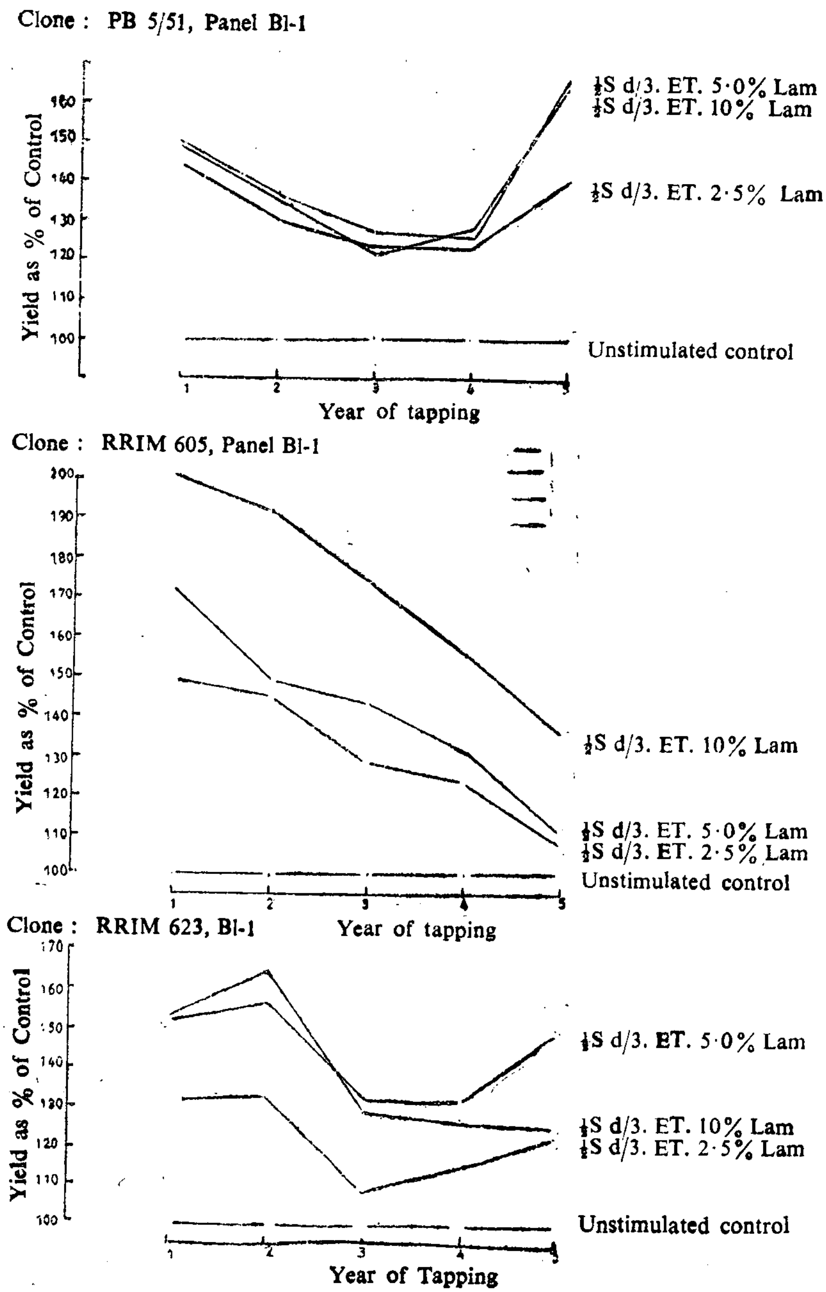


Fig. 4. Relative yield trend

Table 9. *RRIM 605, panels HO - 1 and HO - 2 cumulative yield in kg/ha - ¹ for 3 years*

Treatments	% increase
1/2S d/2 Control	(100)
1/4S ↑ d/2 ET 5% Lam	(203)
1/4S ↑ d/2 ET 2·5% Lam	(173)

Assumed tappable stand/hectare : 296 trees.
Figures within brackets denote percentage values of 1/2S d/2 control.
Actual frequency : 6d/7

Table 10. *PB 5/51, panels Bl - 2 and HO - 2 cumulative yield in kg/ha - ¹ for 4 years*

Treatment	Yield
1/2S d/2 Control	4257 (100)
1/2S d/2 ET 5% Gam*	9676 (227)
1/4S ↑ d/2 ET 5% Gam	9437 (222)
1/8S ↑ d/2 ET 5% Gam	8162 (192)

Assumed tappable stand/hectare : 296 trees
Figures within brackets denote percentage values of 1/2S d/2 control
Actual frequency : 6d/7
*Tapped on 1/2S ↑ d/2 on high panel HO - 1 from beginning to end of third year

Table 11 shows that in clone GT 1 tapped on panels Bl - 2 and HO - 3 1/8S ↑ d/2 ET Lam yielded 136% compared with 1/2S d/2 over a period of 6 years whereas 1/2S d/2 ET 5% Lam only yielded 131%. However, the highest yield was given by 1/3S ↑ d/2 ET 5% Lam and by 1/4S ↑ d/2 ET 5% Lam with 191% and 167%, respectively.

Table 11. *GT 1, panels Bl - 2 and HO - 3 cumulative yield in kg/ha for 6 years*

Treatment	Yield	% increase
1/2S d/2 Control	10294	(100)
1/2S d/2 ET 5% Lam	13412	(131)
I/3S ↑ d/2 ET 5% Lam	19697	(191)
1/4S ↑ d/2 ET 5% Lam	17239	(167)
I/8S ↑ d/2 ET 5% Lam	13971	(136)

Assumed tappable stand/hectare : 296 trees.
Figures within brackets denote percentage values of 1/2S d/2 control.
Actual frequency : 6d/7

In another experiment on GT 1, panels Bl - 1 and HO - 1, 1/4S ↑ d/2 ET 5% Lam yielded 200% compared with 1/4S ↑ d/2 control. Trees tapped on (1/2S + 1/4S ↑) d/3 with no stimulation only yielded 71% compared with 1/4S ↑ d/2, whereas those tapped on 1/2S d/3 ET 5% Lam and 1/4S ↑ d/3 ET 5% Lam yielded 190% over the 30 month period. Among the various treatments, the highest yield was obtained with trees tapped on 1/2S d/3 at 230 cm and 1/2S d/3 ET 5% Lam at 150 cm (Table 12).

Table 12. *GT 1, panels Bl - 1, and HO - 1 cumulative yield in kg/ha - 1 for 30 months*

Treatment	Yield	% increase
1/4S ↑ d/2 Control	3710	(100)
1/4S ↑ d/2 ET 5% Lam	7413	(200)
(1/2S + 1/4S ↑) d/3 unstimulated	2648	(71)
1/2S d/3 ET 5% 4/y	1280	(35)
1/4S ↑ d/3 ET 5% Lam 4/y	5763	(155)
	7043	(190)
1/2S @ 150 cm d/3 ET 5% Lam	1886	(51)
1/2S @ 230 cm d/3 unstimulated	6239	(168)
	8125	(219)

Assumed tappable stand/hectare : 296 trees
Figures with brackets denote percentage values of 1/4S ↑ d/2 control.
Actual frequency : 6d/7

Girth increment, DRC and panel dryness

Panels BO - 1 and BO - 2

Table 13 shows the girth increment, percentage dryness of the tapping panel and the mean DRC of clone PR 255 over the 9-year period. Generally, unstimulated trees had a higher girth increment compared with trees tapped on the same system with stimulation. Among all the systems 1/4S d/2 had the highest girth increment. Good growth was also achieved in trees tapped on 1/2S d/3, 1/2S d/2 and 1/4S d/2 (t,t). Among the stimulated systems, 1/4S d/2 with stimulation had the highest growth rate. The differences in girth increment among trees tapped on the other systems with stimulation are less marked. Generally, stimulated systems appear to have a higher percentage of panel dryness. However, there was no consistent difference in the percentage dryness in trees stimulated with 2·5% Ethephon and those stimulated with 5% Ethephon. Among the unstimulated systems 1/4S d/2 had the highest DRC and 1/2S d/2 had the lowest DRC. Stimulation lowers the DRC value and the effect was more serious in the more intensive tapping systems than in the short cut systems.

In PBIG seedlings, good girth increment was recorded in all the treatments and mild stimulation depressed the increment in most of the treatments. In this experiment, 1/4S d/2 ET 2·5% Ba2m and 1/4S d/2 ET 2·5% had the highest % dryness with 15·9% and 14·0%, respectively, at the end of the 10th year of tapping (Table 14).

Table 13. *PR 255, panels BO - 1 and BO - 2 girth increment, % dryness and mean DRC over 9 years*

Tapping cut	Treatment	d/2 Total girth inc. (cm)	d/2 % dryness	d/2 Mean DRC	d/3 Total girth inc. (cm)	d/3 % dryness	d/3 Mean DRC	d/2 (t,t) Total girth inc. (cm)	d/2 (t,t) % dryness	d/2 (t,t) Mean DRC
I/2S	Control	22·1	0·8	43·5	26·6	0·0	45·0	—	—	—
	ET 2·5% Ba2m	15·8	8·6	37·6	14·3	4·2	39·5	—	—	—
	ET 5% Ba2m	13·9	4·6	36·0	11·9	4·5	37·3	—	—	—
	ET 2·5% Lam	15·2	4·3	38·6	16·6	3·2	40·7	—	—	—
	ET 5% Lam	16·0	9·5	37·2	17·1	1·5	40·2	—	—	—
1/4S	Control	29·2	0·0	47·0	—	—	—	22·5	4·6	44·5
	ET 2·5% Ba2m	20·9	0·0	42·4	—	—	—	14·3	3·3	39·6
	ET 5% Ba2m	19·6	4·5	42·0	—	—	—	12·8	1·9	37·2
	ET 2·5% Lam	20·8	4·6	43·4	—	—	—	20·0	0·7	41·6
	ET 5% Lam	24·3	1·5	43·7	—	—	—	14·6	1·6	39·5

Assumed tappable stand/hectare : 296 trees.
Actual frequency : 6d/7

Table 14. *PBIG seedlings girth increment, % dryness and mean DRC over 10 years*

Tapping cut	Treatment	d/2 Total girth inc. (cm)	d/2 % dryness	d/2 Mean DRC	d/3 Total girth inc. (cm)	d/3 % dryness	d/3 Mean DRC
1/2S	Control	—	—	—	32·2	1·1	42·6
	ET 2·5% Ba2m	—	—	—	33·1	4·8	39·9
	ET 5% Ba2m	—	—	—	31·4	7·7	38·2
	ET 2·5% Lam	—	—	—	27·2	1·2	41·0
	ET 5% Lam	—	—	—	32·2	4·4	40·4
1/4S	Control	38·6	5·0	44·5	37·5	0·0	46·4
	ET 2·5% Ba2m	33·1	15·9	40·4	30·4	4·5	42·8
	ET 5% Ba2m	26·3	3·2	39·8	38·4	0·0	43·4
	ET 2·5% Lam	34·5	14·0	42·7	36·7	1·2	44·5
	ET 5% Lam	28·7	11·8	40·6	36·2	1·0	43·2

Assumed tappable stand/hectare : 296 trees
Actual frequency : 6d/y

In all the treatments, the DRC was high. Stimulation reduced the DRC value, but there was no consistent difference in the DRC of trees stimulated with 2·5% Ethephon and those stimulated with the 5% stimulant.

In RRIM 600 and RRIM 623, higher girth increment was obtained in the 1/4S systems than in the other systems. As in PR 255 and PBIG seedlings, 1/4S systems also yielded latex with high DRC. In RRIM 600 all the trees tapped on 1/2S systems with or without stimulation resulted in high percentage of panel dryness. In trees tapped on the 1/4S cut the percentage of panel dryness was relatively low. In RRIM 623, there was no consistent difference in the percentage of panel dryness in trees tapped on the various systems (Table 15).

In GT 1 panel BO - 1 stimulation reduced girth increment (Table 16). However, the effect is less serious with 2·5% Ethephon than with 5% and 10% Ethephon. Stimulation also increased the percentage of panel dryness and the increase appeared to be more marked in the trees stimulated with 5% and 10% Ethephon than in those stimulated with 2·5% Ethephon. In this trial, stimulation resulted in a slightly lower DRC. In the first 3 years, 10% and 5% Ethephon resulted in the lowest DRC. But in the last 3 years, there was no significant difference in the DRC of latex obtained with the three levels of stimulant.

Panels BO - 2 and BI - 1

RRIM 623 tapped on panel BO - 2 and BI - 1 stimulation with 10%, 5% and 2·5% Ethephon did not appear to affect the percentage of panel dryness over the 4-year period (Table 17). The DRC of 1/4S d/2 (t,t) with 5% and 10% Ethephon was slightly lower than that of 1/2S d/2 control, while 1/4S d/2 (t,t) ET 2·5% gave latex with a slightly higher DRC.

In PB 5/51, RRIM 605 and RRIM 623 tapped on panel BI - 1, stimulation with 10% and 5% Ethephon resulted in a slower growth rate. However, this effect was less serious in trees stimulated with 2·5% Ethephon. In all the three clones the percentage of panel dryness was higher on trees stimulated with 10% Ethephon than on those stimulated with the 5% and the 2·5% stimulant. Stimulation also resulted in a lower DRC and the decrease in DRC value is more in trees stimulated with 10% Ethephon than those stimulated with the 2·5% and 5% stimulant (Table 18).

DISCUSSION AND CONCLUSION

Generally, common *Hevea* cultivars tapped on panels BO - 1 and BO - 2 did not give high and consistent responses to mild stimulation with Ethephon. The responses were particularly poor in RRIM 600 and RRIM 623. However, with PR 255, PBIG seedlings and GT 1, the moderate responses with 2·5% Ethephon is an encouraging feature. In the 1/4S cut systems, the decline in the responses to stimulation over the years was less. Trees tapped on these systems have moderately good growth and the latex has high DRC. The percentage of panel dryness was acceptable and with a short cut system a tapper can also tap more trees. Hence, in areas where labour shortage is a problem, consideration can be given to use these systems to exploit some cultivars tapped on panels BO - 1 and BO - 2.

Table 15. *RRIM 600 and RRIM 623 panels BO - 1 and BO - 2 girth increment, % dryness and mean DRC over 10 years*

		d/2						d/3					
		RRIM 600			RRIM 623			RRIM 600			RRIM 623		
Tapping cut	Treatment	Total girth inc. (cm)	% dryness	Mean DRC	Total girth inc. (cm)	% dryness	Mean DRC	Total girth inc. (cm)	% dryness	Mean DRC	Total girth inc. (cm)	% dryness	Mean DRC
1/2S	Control	25·3	22·6	36·3	25·3	3·7	42·6	—	—	—	—	—	—
	ET 2·5% Ba2m	—	—	—	—	—	—	—	—	—	—	—	—
	ET 5% Ba2m	23·1	31·2	32·7	—	—	—	24·0	22·1	34·0	19·5	19·3	39·6
	ET 2·5% Lam	—	—	—	18·1	8·1	40·2	—	—	—	—	—	—
	ET 5% Lam	22·4	29·8	32·2	15·8	14·7	38·6	22·4	6·5	33·7	18·2	21·7	41·3
1/4S	Control	—	—	—	25·5	15·1	44·9	—	—	—	—	—	—
	ET 2·5% Ba2m	24·6	2·8	35·6	—	—	—	—	—	—	—	—	—
	ET 5% Ba2m	27·0	12·2	36·3	—	—	—	—	—	—	—	—	—
	ET 2·5% Lam	30·2	1·0	38·3	24·4	7·4	43·9	—	—	—	—	—	—
	ET 5% Lam	27·6	4·8	37·0	23·5	1·2	43·4	—	—	—	—	—	—

Assumed tappable stand/hectare : 296 trees
Actual frequency : 6d/7

Table 16. *GT 1 — panel BO - 1*

	1st — 3rd Year				4th — 6th Year		
Treatment	Total girth inc. (cm)	% dryness	Mean DRC	Treatment	Total girth inc. (cm)	% dryness	Mean DRC
1/4S d/3 (t,t) control	15·8	3·1	38·1	1/2S d/3 control	11·3	2·8	38·3
1/4S d/3 (t,t) ET 10% Lam	12·8	4·2	36·3	1/2S d/3 ET 10% Lam	8·6	4·5	38·1
1/4S d/3 (t,t) ET 5% Lam	13·5	8·7	36·3	1/2S d/3 ET 5% Lam	8·3	12·1	37·0
1/4S d/3 (t,t) ET 2·5% Lam	15·4	8·8	37·1	1/2S d/3 ET 2·5% Lam	10·2	4·2	37·9

Tapping system from the first to the third year was 1/4S d/3 (t,t) and from the fourth to sixth year it was 1/2S d/3.
Assumed tappable stand/hectare : 296 trees
Actual frequency : 6d/7

Table 17. *RRIM 623, panels BO - 2 and BI - 1* percentage *dryness and mean DRC.*

Treatment	% dryness	Mean DRC
1/2S d/2 Control	5·2	40·3
1/4S d/2 (t,t) ET 10% Lam	4·3	39·2
1/4S d/2 (t,t) ET 5% Lam	3·3	39·9
1/4S d/2 (t,t) ET 2·5% Lam	6·4	41·0

Assumed tappable stand/hectare : 296 trees
Actual frequency : 6d/7

In RRIM 623, and GT 1 tapped on panels BO - 2 and BI - 1 with 1/4S d/2 (t,t) the response to stimulation with 5% Ethephon had been low but positive. Clone GT 1 also responded moderately well to 1/2S d/2 ET 5% Lam. In PB 5/51, and RRIM 623, panel BI - 1, tapped on 1/2S d/3 the responses to 2·5% and 5% Ethephon stimulation were comparable to the responses to stimulation with the 10% stimulant.

In RRIM 605 higher Ethephon concentration gave a higher response. In all the three clones, the decline in responses to stimulation over the years was slower in trees stimulated with a lower stimulant concentration than in those stimulated with higher dosage. The slow decline in responses together with a better growth rate of the stimulated trees and a lower stimulant cost makes mild stimulation with 2·5% and 5% Ethephon more attractive in the long-term than with the 10% stimulant.

The results with RRIM 605, PB 5/51 and GT 1 show that in older trees tapped on panels HO - 1 and HO - 2 1/4S ↑ d/2 ET 5% may be profitably used to exploit the virgin bark on the high panels.

ACKNOWLEDGEMENT

The authors wish to thank Encik Ahmad Zarin and Encik Ng Kar Foo for their technical help and the many field workers involved in the series of trials discussed in this paper. The kind approval from the directorate for permission to publish this paper is also appreciated.

REFERENCES

ABRAHAM, P. D. (1970). Field trials with Ethrel. *Plrs' Bull. Rubb. Res. Inst. Malaya* No. **111**, 366.

ABRAHAM, P. D., P' NG, T. C., LEE, C. K., SIVAKUMARAN, S., MANIKAM, B. AND YEOH, C. P. (1975). Ethrel stimulation of *Hevea. Proc. Int. Rubb. Conf. Kuala Lumpur* 1975, **2**, 347.

ISMAIL HASHIM, AHMED ZARIN, OTHMAN HASHIM, YOON, P. K. AND P'NG, T. (1981). Further results of controlled upward tapping on high panels. *Proc. Rubb. Res. Inst. Plrs' Conf. Kuala Lumpur* 1981, 74.

Table 18. *PB 5/51, RRIM 605 RRIM 623, panel BI - I girth increment, % dryness and mean DRC over 5 years*

Treatment	PB 5/51* Total girth inc. (cm)	PB 5/51* % dryness	PB 5/51* Mean DRC	RRIM 605 Total girth inc. (cm)	RRIM 605 % dryness	RRIM 605 Mean DRC	RRIM 623 Total girth inc. (cm)	RRIM 623 % dryness	RRIM 623 Mean DRC
1/2S d/3 control	7·0	4·3	45·6	7·0	0·0	46·1	9·4	1·1	48·5
1/2S d/3 ET 10% Lam	5·9	7·7	42·2	5·1	4·7	43·5	6·9	3·7	46·8
1/2S d/3 ET 5% Lam	5·8	4·3	42·6	5·2	2·9	43·9	7·7	0·6	47·8
1/2S d/3 ET 2·5% Lam	6·0	6·5	43·6	6·7	0·5	45·1	9·0	2·7	47·8

Assumed tappable stand/hectare : 296 trees
Actual frequency : 6d/7
*The 5th year was tapped on panel HO - 1

DISCUSSION

Q — C. BARLOW, Australia : Please explain about the consistency of your results between locations.

A — C. K. LEE, Malaysia : The results you see here this morning are mainly from Kedah and from trials from Johore and Selangor. From our experience the results are quite consistent, the trials you see are mainly 5 - 10 years old. We have newer trials coming up. The results are very consistent it can be repeated.

INTEREST OF ETHREL STIMULATION ASSOCIATED WITH LOW FREQUENCY OF TAPPING ON *HEVEA* IN THE IVORY COAST

BY

J. M. ESCHBACH* AND Y. BANCHI**

(*IRCA — 01 BP 1536 Abidjan 01, Ivory Coast and **SAPH — 01 BP 1322 Abidjan 01, Ivory Coast)

ABSTRACT

In the Ivory Coast, the first tappings on estates were carried out on full spirals twice a week.

From 1975, the use of stimulation has made it possible to decrease the tapping intensity while maintaining an identical level of yield and growth, fewer dry trees and good physiological characteristics.

Results of trials and the observation of the development of yields from estates do not show, after 7 or 8 years, any relative fall in yield and serve to confirm the practical advantages of stimulation when used rationally.

INTRODUCTION

The first estates in the Ivory Coast date from 1953, and the techniques employed reflect those used by planters in Cambodia and Vietnam, that is : full spiral and two tappings per week (S d/3 6d/7).

This system, used until 1975, was sometimes combined, essentially on seedlings, with stimulations with 2 – 4, D.

In 1969, both in Malaysia (Abraham *et al*, 1968) and in the Ivory Coast (D'Auzac and Ribailler, 1969), stimulation with Ethrel proved to be effective on *Hevea,* and a great many studies were carried out at IRCA, in association with the estate companies, on the use of this chemical.

These studies have shown that the stimulation of young trees tapped on S d/3 6d/7 provokes a significant over-production but rapidly leads to serious physiological problems which compromise the economic life of the tree.

In 1971, experiments set up on grafted trees at opening aimed at obtaining, at lower tapping intensity balanced by stimulation, not an over-production, but a level of yield appreciably equal to the S d/3 6d/7, without the physiological drawbacks of this system considered as a control.

The first results obtained (Gener and du Plessix, 1975) showed the advantages of this system both from a physiological and economic view point.

The following tapping system is now thus in general use in the Ivory Coast : 1/2 S. d/3 6d/7. ET 4 or 5%. Ba 2 (2). 4/y.

This study takes stock of the reaction of the tree, after 6 or 7 years of exploitation, to this system of lower tapping intensity combined with stimulation, in comparison with the control system used previously : S d/3 6d/7 non stimulated.

MATERIALS AND METHODS

Trials in the Ivory Coast were applied to several clones, at opening or after some years of tapping in S d/3 6d/7 non stimulated.

The first results of the orientation exploitation trials (EOE A to D) have already been published (Gener and du Plessix, 1975). This type of trial numbers 30 trees per treatment. The control was tapped on full spiral twice a week with four annual stimulations on scraped bark with 2g of a mixture of Ethrel and palm oil at 5% concentration of active ingredient (1/2 S. d/3 6d/7. ET 5%. Ba 2 (2) 4/y). These trials have lasted 4 to 6 years, maximum time allowed for reliability, in view of the small number of trees.

Agronomical exploitation experiments (EAE A to F) were directed on around 1 ha. per treatment (4 repetitions of 100 trees per elementary plot). The treatments are the same as for the EOE.

The comparative clonal field was planted in 1969. Opening took place from 1974 to 1976 according to clones with two tapping systems : S. d/3 6d/7 non stimulated and ½ S. d/3 6d/7. ET 5%. Ba 2 (2). 4y, according to a split-plot design : 4 repetitions of around 150 trees per plot.

Trees were given an annual resting period of 2 months, except in estates, which, for the full spiral tapped twice a week, corresponds to a tapping intensity of 95% and for the half spiral to an intensity of 48%.

Observations and collections were based on the g/t for the EOE and the kg/ha/year for the EAE, as well as on the growth of circumference, the percentage of dry trees, the dry rubber and sucrose content of latex, together with the mineral content of the leaves.

The results relative to SAPH estates relate to 79·44 ha spread between three estates and opened from 1962 to 1972. The planting material is composed of seedlings and grafted trees with some high yielding budded trees (GT 1, PR 107, PB 86). Table 1 summarizes the origin of the results.

RESULTS

Yield

Table 2 regroups, by clone and by year of trial, yields relative to the two treatments studied, in g/t for the EOE and in kg/ha for the EAE.

Table 1. *Characteristics of material studied*

		Location	Material (planting)	Beginning of treatments	No. of trees or area (ha)	Period (years)
EOE	A	Auguédédou	GT 1 (1965)	1971 (opening)	30 trees	6
	B	,,	PR 107 (1966)	1973 (opening)	30 trees	5
	C	,,	PB 86 (1962)	1974 (6 years of tapping)	30 trees	4
	D	,,	PB 5/51 (1966)	1972 (opening)	30 trees	5
EAE	A	Anguédédou	GT 1 (1966)	1972 (opening)	4 x 100 trees	4
	B	,,	GT 1 (1966)	1977 (5 years of tapping)	4 x 100 trees	6
	C	,,	PR 107 (1968)	1975 (opening)	4 x 100 trees	7
	D	Toupah	PR 107 (1960)	1972 (4 years of tapping)	4 x 60 trees	7
	E	,,	PB 86 (1960)	1972 (5 years of tapping)	4 x 60 trees	7
	F	Anguédédou	PB 5/51 (1968)	1975 (1 year of tapping)	5 x 65 trees	4
Comp. clonal field		Anguédédou	5 clones (1969)	1974/76 (opening)	4 x 75 trees	8
		Toupah	58% seedlings 42% budded (13% budded H.Y.) planted before 1968	1975	3 919 ha	8
Estate		Ousrou	100% budded (69% budded H.Y.) planted before 1968	1975	1 481 ha	8
		Bongo	75% seedlings 25% budded (16% budded H.Y.)	1975	2 544 ha	8

Table 2. *Yield in g/t (EOE) and in kg/ha⁻¹ y⁻¹ (EAE) for different clones in relation to treatments year by year*

Clones	Trials	Treatments	Years 1	2	3	4	5	6	7	Total % control
	EOE A	S. d/3 control	1959	2964	3745	3379	4028	4010		
		1/2S. d/3 ET	1758	2676	4478	4582	5070	5892		118
		(% control)	(90)	(90)	(120)	(136)	(126)	(147)		
	EAE A	S. d/3 control	1315	1448	1691	1827				
GT 1		1/2S. d/3 ET	1173	1784	2191	2152				115
		(% control)	(89)	(123)	(130)	(118)				
	EAE B	S. d/3 control	2545	3012	2880	2254	1661	1036		
		1/2S. d/3 ET	2495	3486	3321	3039	2202	1757		128
		(% control)	(98)	(116)	(115)	(135)	(133)	(170)		
	EOE B	S. d/3 control	1427	2290	2861	4176	5521			
		1/2S. d/3 ET	2065	3596	3941	4922	5825			133
		(% control)	(145)	(157)	(138)	(118)	(106)			
	EAE C	S. d/3 control	805	1372	1708	1962	1809	1691	2125	
PR 107		1/2S. d/3 ET	846	1587	1754	2103	2042	2514	2402	115
		(% control)	(105)	(116)	(103)	(107)	(113)	(149)	(113)	
	EAE D	S. d/3 control	2112	2113	1940	1526	1858	1544	1582	
		1/2S. d/3 ET	1859	2299	2466	2095	2183	1964	1861	118
		(% control)	(88)	(109)	(127)	(137)	(117)	(127)	(118)	
	EOE C	S. d/3 control	2092	2851	3079	4183				
		1/2S. d/3 ET	2234	3446	4355	5017				122
		(% control)	(107)	(121)	(141)	(120)				
PB 86	EAE E	S. d/3 control	1474	1388	1312	1541	1445	1533	1344	
		1/2S. d/3 ET	1180	1556	1646	1817	1700	1920	1644	114
		(% control)	(80)	(112)	(125)	(118)	(118)	(125)	(122)	
	EOE D	S. d/3 control	1391	2141	4017	4409	5103			
		1/2S. d/3 ET	1310	2319	4251	5085	5152			105
		(% control)	(94)	(108)	(106)	(115)	(101)			
PB 5/51	EAE F	S. d/3 control	845	1262	1256	1622				
		1/2S. d/3 ET	852	1233	1283	1651				101
		(% control)	(101)	(98)	(102)	(101)				
Mean	EAE BDE	(% control)	89	112	122	130	123	141		

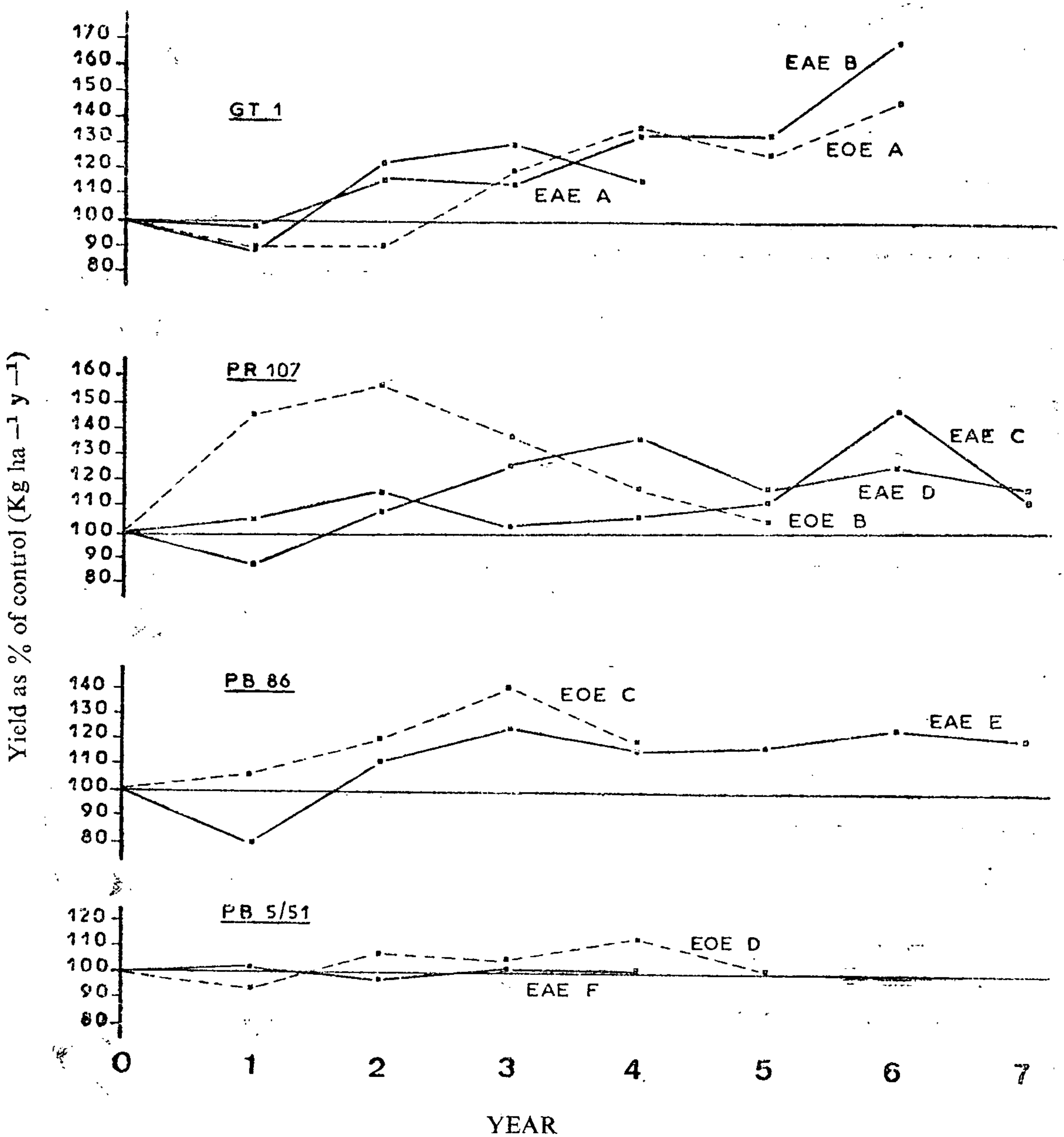


Fig. 1. Trend of yield of ½S stimulated in percentage of yield of S non stimulated.

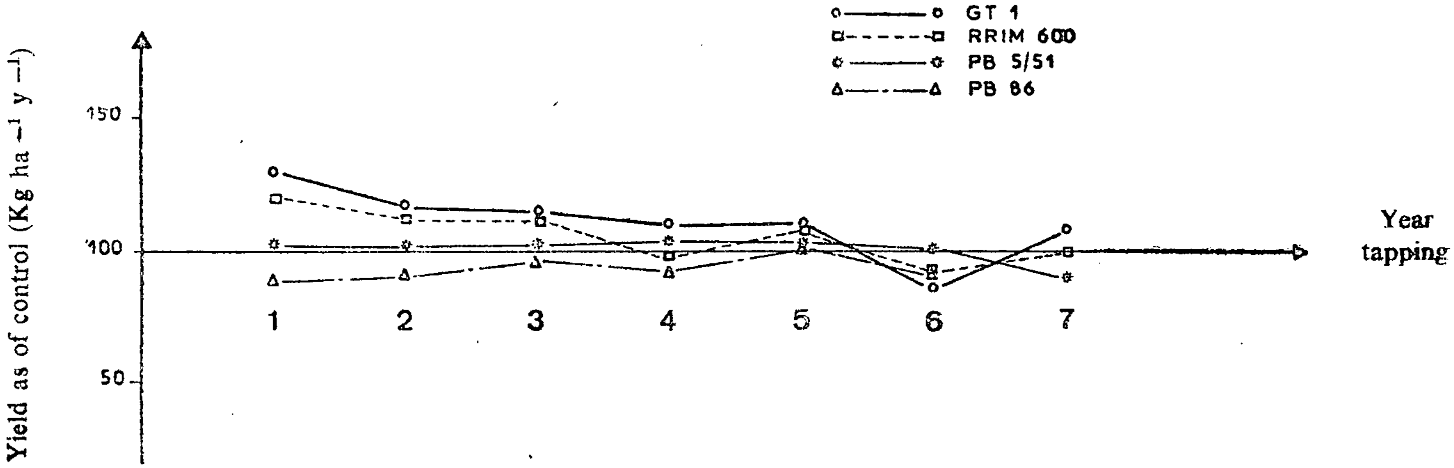


Fig. 2. Trend of kg / ha / year of 1/2 S stimulated in percentage of S stimulated for clonal field.

Figs. 1 and 2 trace the development of the yield of the stimulated treatment in comparison with the non-stimulated treatment for experiments relating to exploitation and the comparative clonal field.

On GT 1, at opening, the yield of the stimulated treatment, which was lower than the control in the first and sometimes in the second year, increases to a higher level than the non-stimulated treatment. The development of yields does not seem to show a fall compared with the control in the long term.

In the clonal field, the relative fall of the 1/2 S in the sixth year corresponds with the rise of the full spiral. Over 7 years of the trial, the cumulated yield of the 1/2 S stimulated represents 108% of the yield of the S non-stimulated.

For PR 107, the development of the yield in relation to the control does not display a tendency to drop, with the exception of the EOE, and over 7 years the cumulated yield of the EAE C and D represents 115 and 118% of the yield of the S non-stimulated.

PB 86 maintains as from the third year of experimentation (EAE. E) an over-production of over 20% more or less constant in relation to the control. In the clonal field, at opening, the yield of the two treatments are identical.

The same thing goes for the PB 5/51 (EOE D, EAE F and comparative field) and the RRIM 600 (comparative field). Stimulation makes it possible to compensate exactly for the drop in yield due to a decrease by half of the tapping intensity.

On estates, Fig. 3 shows a gradual increase in yields following upon the opening of trees until 1971/72. The whole crop went over to 1/2 S stimulated with Ethrel 4 to 6 times a year from 1975 after having been tapped in S (non-stimulated). From this date and until 1983, the yield remained stable. From 1975 – 1977 a slight decrease in yield is to be noted, linked with labour problems (non-tapping tasks). The increases in yield noted as from this date are due to the greater use of upward tapping.

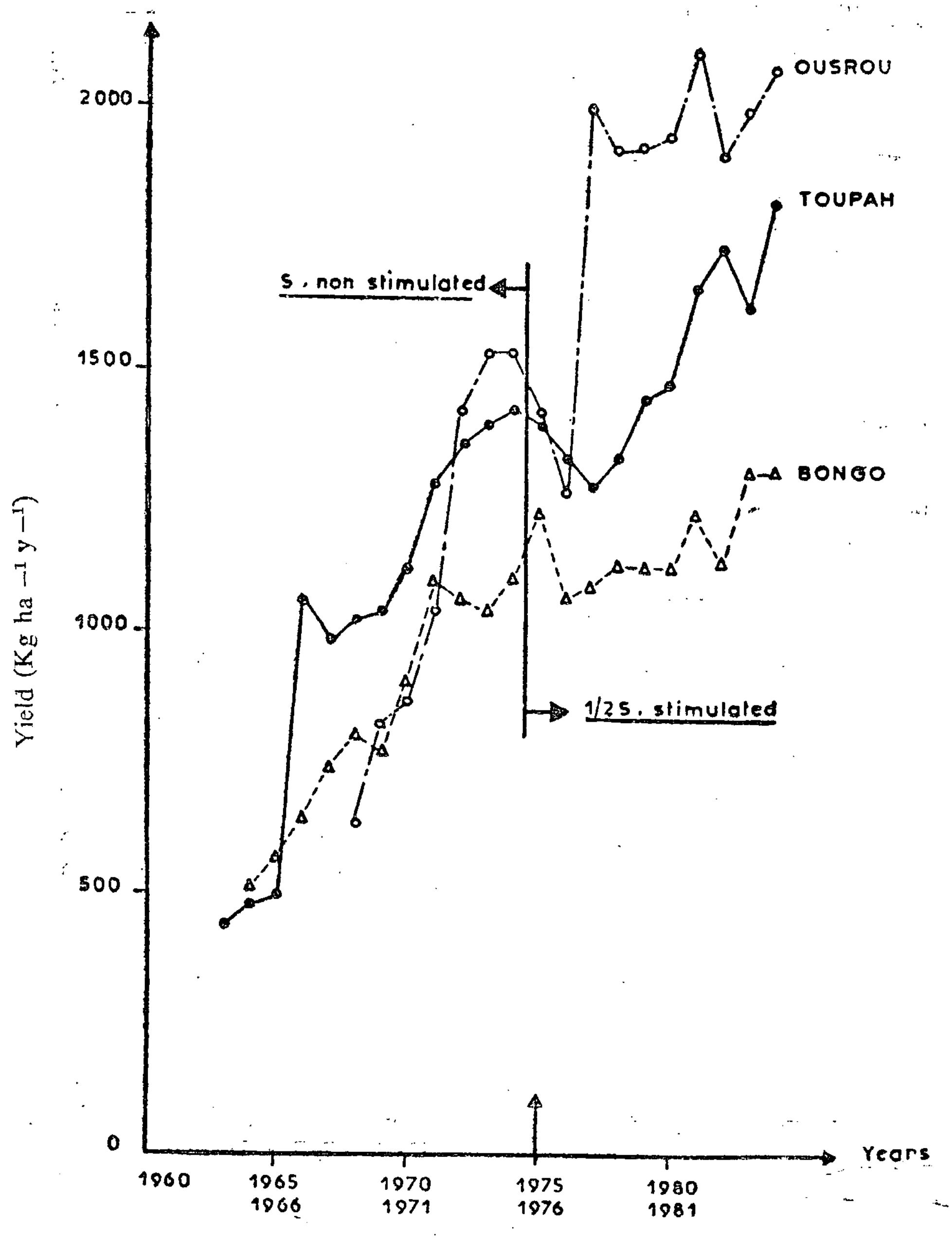
Dry trees

Table 3 expresses the number of trees untapped for reasons of dry cut, the last year of the trial for each clone studied.

With the 1/2 S stimulated treatment, the percentages of untapped trees are always lower for the overall number of clones. It is, generally speaking, twice as low for the GT 1 and the PB 86 and 3 – 10 times lower for the other clones with the exception of PR 107 for which no differences between the two treatments are to be observed.

Growth

Table 3 shows the growths of circumference measured for each of the clones since the start of the trials.



YEAR

Fig. 3. Trend of yield for estates

Table 3. *Dry trees and girth increment*

Clone		% dry trees			Girth increments (cm)			
GT 1	Experiment	EAE A	EAE B	Clonal field	EAE A	EAE A	EAE B	Clonal field
	(year)	(4)	(5)	(8)	(5)	(4)	(5)	(8)
	S. d/3 control	7,1	12,9	14,2	11,7	12,3	6,4	15,1
	1/2S, d/3 ET	3,0	5,8	1,7	16,3	14,0	6,5	15,1
PR 107	Experiment (year)	EAE C (7)	EAE D (7)		EAE B (5)	EAE C (6)	EAE D (6)	
	S. d/3 control	0,9	21,1		15,0	12,3	10,5	
	1/2S, d/3 ET	1,6	19,9		16,2	10,5	8,4	
PB 86	Experiment	EAE E	Clonal field		EOE C	EAE E	Clonal field	
	(year)	(7)	(8)		(4)	(6)	(8)	
	S. d/3 control	26,2	9,1		5,2	5,4	12,4	
	1/2S. d/3 ET	15,0	4,2		7,4	5,2	13,8	
PB 5/51	Experiment	EAE F	Clonal field		EOE D	EAE F	Clonal field	
	(year)	(3)	(8)		(4)	(4)		
	S. d/3 control	4,6	22,0		12,3	10,3	14,4	
	1/2S. d/3 ET	1,3	3,2		12,3	9,3	15,7	
AVROS 2037	Experiment	Clonal field			Clonal field			
	(year)	(8)			(8)			
	S. d/3 control	5,7			21,5			
	1/2S. d/3 ET	1,7			19,2			
RRIM 600	Experiment	Clonal field			Clonal field			
	(year)	(8)			(8)			
	S. d/3 control	18,1			15,3			
	1/2S. d/3 ET	1,6			15,5			

Trees tapped in 1/2 S show, as a general rule, an identical or higher growth rate to that of trees tapped in S non-stimulated. The PR 107 is, however, and exception to the rule in two out of three trials.

Rubber and sucrose content of latex

Table 4 shows that the dry extract is very often higher by 1 — 4 points for stimulated treatments compared with treatments that are non-stimulated.

From one year to another, the collection periods for latex analysis were different and explain the strong variations observed. On the whole, the sucrose content is not lower for stimulated treatments (Table 5).

Mineral content of leaves

The N, P, K and S content of stimulated treatments is satisfactory and significantly higher than the content of non-stimulated treatments inspite of an identical or better exploitation of latex, at experimental as well as at estate level (Table 6).

Table 4. *Dry rubber content* (%)

Clones	Experiment	Treatments	Years 1	2	3	4	5	Mean	% Control
GT 1	EOE A	S. d/3 control	34,7	26,5	29,8	32,5	31,5	31,0	100
		1/2S. d/3 ET	36,1	31,1	33,3	35,5	35,8	34,4	111
	EAE A	S. d/3 control	ND	29,2	32,8	33,8		31,9	100
		1/2S. d/3 ET		31,8	29,4	30,8		30,7	96
	EAE B	S. d/3 control	33,9	31,1	35,9	ND	ND	33,6	100
		1/2S. d/3 ET	37,0	33,5	31,6			34,0	102
PR 107	EOE B	S. d/3 control	31,0	38,3	39,0	34,4	39,6	36,5	100
		1/2S. d/3 ET	29,2	37,0	40,8	35,7	39,4	36,4	100
	EAE C	S. d/3 control	35,1	36,7	34,4	34,3	37,9	35,7	100
		1/2S. d/3 ET	38,1	38,1	34,6	34,1	41,1	37,2	104
PB 86	EOE C	S. d/3 control	ND	37,8	ND	33,1		35,5	100
		1/2S. d/3 ET		41,0		31,1		36,1	102
PB 5/51	EOE D	S. d/3 control	36,4	34,9	39,3	38,0	ND	37,2	100
		1/2S. d/3 ET	36,0	34,0	39,0	44,6		38,4	103
	EAE F	S. d/3 control	34,1	40,3	37,9	ND		37,4	100
		1/2S. d/3 ET	38,2	43,2	42,1			41,2	110

ND : non determined

Table 5. *Sucrose content (mg/ml latex)*

Clones	Experiment	Treatments	Years 1	2	3	4	5	Mean	% Control
GT 1	EOE A	S. d/3 control	0,43	0,68	0,65	1,14	1,20	0,82	100
		1/2S. d/3 ET	1,11	1,16	1,26	1,79	1,28	1,32	161
	EAE A	S. d/3 control	ND	1,23	1,38	ND		1,31	100
		1/2S. d/3 ET		1,35	0,77			1,06	81
	EAE B	S. d/3 control	ND	0,7	1,9	ND	ND	1,30	100
		1/2S. d/3 ET		0,6	2,4			1,50	115
PR 107	EOE B	S. d/3 control	3,65	1,56	0,99	1,81	0,80	1,76	100
		1/2S. d/3 ET	1,89	0,94	0,56	1,99	3,10	1,70	100
	EAE C	S. d/3 control	ND	ND	1,8	4,3	1,18	2,43	100
		1/2S. d/3 ET			2,1	3,0	1,96	2,35	97
PB 86	EOE C	S. d/3 control	ND	0,95	ND	2,5		1,73	100
		1/2S. d/3 ET		1,38		2,2		1,79	103
PB 5/5	EOE D	S. d/3 control	0,79	0,64	0,61	0,85	ND	0,73	100
		1/2S. d/3 ET	0,76	0,67	0,48	0,80		0,68	93
	EAE F	S. d/3 control	3,4	ND	0,7	ND		2,05	100
		1/2S. d/3 ET	2,1		0,9			1,50	73

ND : non determined.

Table 6. *Mineral composition of leaves*

Clones experiments	Treatments	Leaves mineral content					
		N %	P %	K %	Ca %	Mg %	S ppm
GT 1 EAE B 4th year	S. d/3 control	3,57	0,191	0,86	0,70	0,362	214
	1/2S. d/3 ET	4,43*	0,299*	1,11*	0,95*	0,422*	309*
PR 107 EAE C 5th year	S. d/3 control	3,72	0,236	0,85	0,92	0,413	264
	1/2S. d/3 ET	4,79*	0,271	1,22*	0,57*	0,267*	367*

DISCUSSION AND CONCLUSION

The dangers of stimulation used on a 1/2S d/2 system have recently been pointed out (Sivakumaran and Pakianathan, 1981). Compared with the non-stimulated control, yields fall from the fourth year and become lower than those of the control in the seventh year. This decrease in the response to stimulation has been associated with too great an exploitation of latex, which does not allow the tree to synthesize the latex from the drained area, when the tapping frequency is too great (Pakianathan *et al*, 1982). With lower intensity systems such as d/4 or d/6 or with shorter cuts, 1/4S, the response to stimulation is sustained and the cumulated yields become, at the end of 7 – 9 years, higher than those of 1/2S. d/2 stimulated (Sivakumaran *et al*, 1982 and 1983). In the last case, with 2g of the chemical at 10% active ingredient applied 6 times per year, trees receive 1.200 mg of active ingredient per tree per year. Applied at a tapping intensity of 100% (1/2S d/2) the extra yield obtained compared with the control 1/2S d/2 varies in the first years from 100 – 250%. It is, moreover, at this tapping intensity that stimulation produces the highest yield (Paardekooper *et al*, 1975).

Following work carried out in Vietnam (Campaignolle, 1955) and the first results obtained in the Ivory Coast (D'Auzac and Ribaillier, 1969) stimulation has been used to make it possible to obtain in 1/2S d/3 6d/7 10 m/12 (tapping intensity : 48%) a yield at least equivalent to one in S d/3 6d/7 10 m/12 (tapping intensity : 96%). With 2g or the chemical at 5% active ingredient applied four times per year, the trees receive 400 mg of active ingredient per tree and per year.

Stimulation used here in doses that are three times weaker than in the Far East on tapping intensity systems two times lower do not lead to spectacular increases in yield but make it possible to maintain a level of yield that is equal or slightly higher to that of the control without there being in the long run a relative fall in yield.

Factors leading to an increase in yield by stimulation and the dangers of over-stimulation are beginning to be understood (Jacob *et al*, 1983). The dryness of the cut is one of the first signs of over-stimulation. Results obtained here show that 1/2S stimulated are far less prone to dry cuts than S non-stimulated, for all clones full spiral leading to more dry cuts than the stimulation of 1/2S.

For identical or higher exploitations of latex, the 1/2S does not lead to lower growth rate than those obtained with S non-stimulated. These results confirm observations already made elsewhere (Paardekooper *et al*, 1975).

Ethrel treatments always entail a decrease in rubber content. This decrease in DRC is here more than compensated by the decrease in tapping intensity. A lower sucrose content, which could be indicative of an exhausting of glucidic reserves of the tree, has not been noted.

As for the mineral elements in the leaves, analyses carried out show that the content in N, P, K, Ca, Mg and S are nearly always, for GT 1 and PR 107, significantly higher with stimulated treatments.

In the comparative clonal field, 10 years of observation show no difference between the two treatments for the mineral content in the leaves of GT 1, PB 5/51, RRIM 600 and AVROS 2937.

Within the prevailing economic conditions of the Ivory Coast, at the same level of yield, the cost of stimulation is more than compensated by the decrease in the cost of tapping resulting from a larger tapping task.

It is, therefore, possible to compensate by stimulation for a lower tapping intensity without harmful effect on the tree in the long term, both at yield level and the physiological characteristics of the tree.

All these results have been widely confirmed on an industrial scale by the estate companies which, in the Ivory Coast, opted very early on for the rational use of the possibilities offered by Ethrel. The SAPH is a very good example of this. This company exploits, with the technical assistance of SODECI, over 20,000 ha of rubber plantations, 14,000 ha of which are tapped. Until 1974, the tapping system used by the SAPH was S d/3 6d/7, but now the following systems are used :

(1) from opening, on the basis of reduced tapping intensity (1/2S d/3 6d/7 and 1/2S d/4 6d/7).

(2) stimulation modulated by Ethrel, also from opening, to compensate the decrease in the frequency of tapping and to determine the production level according to the recognized yield potential of the trees (6 – 8 stimulations per year on 1/2S d/4 6d/7).

Stimulation also lowers the cost of tapping and the consumption of bark when used rationally.

Recent results (Eschbach and Tonnelier, 1984) prompt us to recommend with 1/2S., 8 – 10 applications on the panel of 1g of a mixture at 2·5% active ingredient.

REFERENCES

ABRAHAM, P. D., WYCHERLEY, P. R. AND PAKIANATHAN, S. W. (1968). Stimulation of latex flow in *Hevea brasiliensis* by 4 amino 3-5-6 trichloropicolonic acid and 2-chloroethane phosphonic acid. *J. Rubb. Res. Inst. Malaya.* **20,** 291 — 305.

CAMPAIGNOLLE, J. (1955). Vers l'utilisation de la stimulation comme methode normale d'exploitation. *Bulletin caoutchouc, serie Indochine,* **14,** 25.

D'AUZAC, J. et RIBAILLIER, D. (1969). L'ethylene, nouvel agent stimulant la production due latex chez l' *Hevea brasiliensis. C. R. Acad. Sci. Paris, 268,* serie D, 3046 — 3049.

ESCHBACH, J. H. et TONNELIER, M. (1984). Influence du mode de stimulation, de la concentration du produit stimulant et de la frequence d'application sur la production du GT 1 en Cote d'Ivoire. *Meeting IRRDB, Physiologie Exploitation, Montpellier* 1984.

GENER, P. AND DU PLESSIX, C. J. (1975). Effective use of tapping systems and stimulation methods toward rational exploitation of *Hevea. Proc. Int. Rubber Conf. Kuala Lumpur*, 1975, **2,** 384 — 395.

JACOB, J. L. PREVOT, J. C. et D' AUZAC, J. (1983). Augmentation de la production de l'*Hevea* par l'ethylene. *Caout. Plast.*, **631,** 87 — 89.

PAARDEKOOPER, E. C., LANGLOIS, S. J. C. AND SOMPONG SOOKARK (1975). Influence of tapping intensity and stimulation on yield, girth and latex constitution. *Proc. Int. Rubb. Conf. Kuala Lumpur*, 1975. **2,** 290 — 314.

PAKIANATHAN, S. W., SAMSIDAR, B. H. SIVAKUMARAN AND GOMEZ, J. B. (1982). Physiological and anatomical investigations on long term ethephon stimulated trees. *J. Rubb. Res. Inst. Malaysia*, **30,** 63 — 79.

SIVAKUMARAN, S., PAKIANATHAN, S. W. AND GOMEZ, J. B. (1981). Long term ethephon stimulation. I. Effects of continuous ethephon stimulation with half spirals alternate daily tapping. *J. Rubb. Res. Inst. Malaysia*, **29,** 57 — 85.

SIVAKUMARAN, S., PAKIANATHAN, S. W. AND ABRAHAM, P. D. (1982). Long term ethephon stimulation. II. Effect of continuous ethephon stimulation with low frequency tapping systems. *J. Rubb. Res. Inst. Malaysia*, **30,** 174 — 196.

SIVAKUMARAN, S., PAKIANATHAN, S. W. AND ABRAHAM, P. D. (1983). Long term ethephon stimulation with short cut panel-changing system. *J. Rubb. Res. Inst. Malaysia*, **31,** 151 — 174.

STUDIES ON EXPLOITATION OF NEWER CLONES IN SRI LANKA

By

CHANDRA SAMARANAYAKE AND A. G. A. de SOYSA
(*Rubber Research Institute, Sri Lanka*)

ABSTRACT

The early maturing, high yielding RRIC 100 series clones are replacing the clones that were planted in the late 1950's and early 1960's. Exploitation systems used for the older clones may not necessarily be the most suitable systems for these clones with a high yield potential.

An attempt is made in these studies to determine the most suitable method of exploitation of these newer clones.

INTRODUCTION

Improvement of methods of exploitation is a subject for continuous research, whenever new clones are introduced, studies for suitable methods of exploitation should go hand in hand with the evaluation of clones for different climatic regions.

RRIC 100 series clones bred from 1957 onwards were introduced into plantations in the early 1970's (Chandrasekera, 1973). They were planted on a small scale at the start, now these clones are increasing in popularity and are replacing the older clones on favourable yields and other secondary characters. The Rubber Research Institute of Sri Lanka (RRISL) now recommends RRIC 100 and 103 for large scale planting (Jayasekera and Fernando, 1981) and clone RRIC 102 has been introduced recently into plantations for small scale planting (Fernando, 1984). Clone RRIC 101 also has been planted to a small extent because of its very high immature vigour and initial high yields. Due to its high tendency towards brown bast, planting of this clone has been discouraged.

This paper discusses the methods of exploitation that are in use and investigations in progress to evaluate suitable exploitation systems for the recently introduced 100 series clones.

Growth vigour and yield potential

Until recently PB 86 was the most widely planted clone in Sri Lanka, but RRIC 100 series clones surpass PB 86 in growth and yield (Fig. 1). The tappability of different clones at 5·5 years from planting is summarised in Table 1.

Table 1. *Tappability (%) at 5·5 years from planting*

Clone	RRIC 100	RRIC 101	RRIC 102	RRIC 103	RRIM 600	PB 86
Tappability (%)	60	72	77	69	30	27

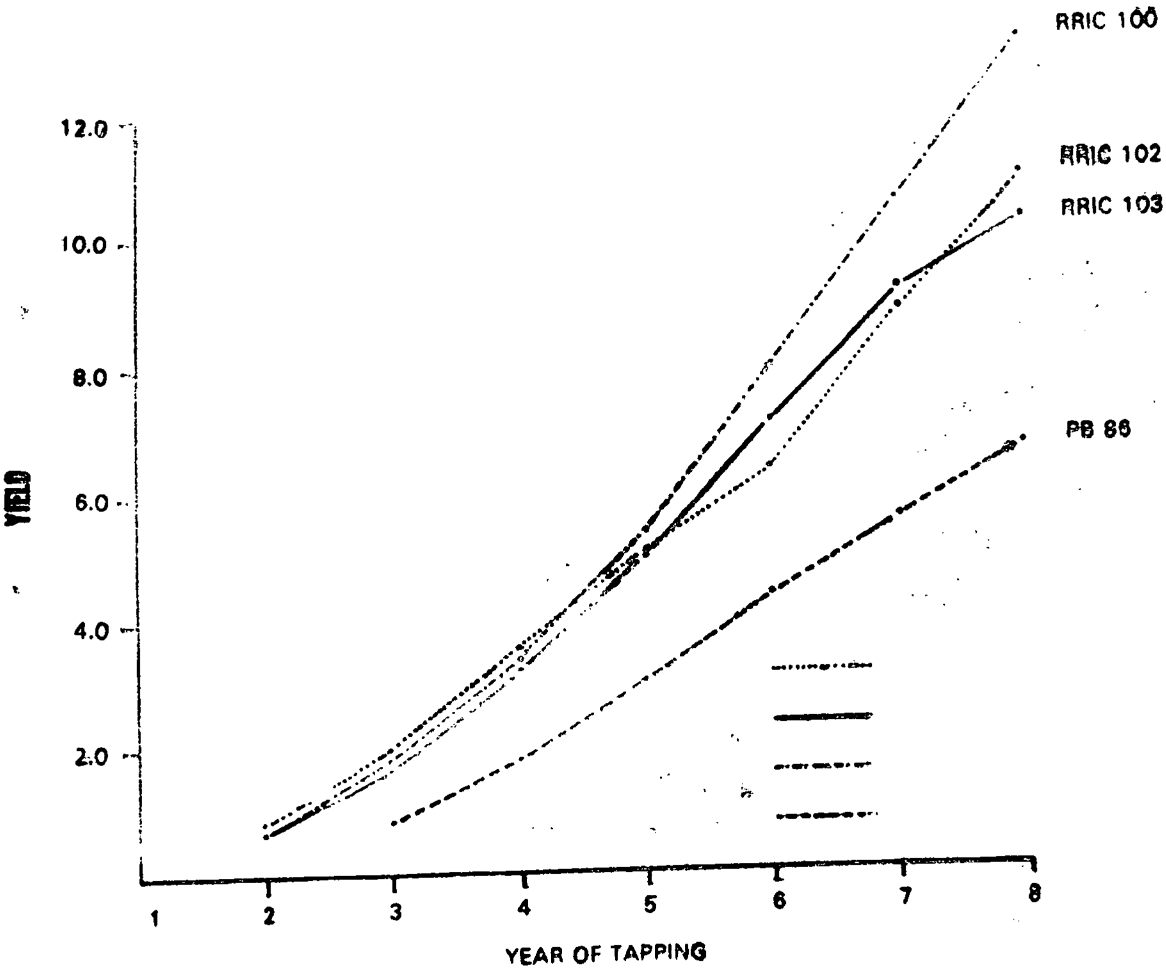


Fig. 1. Cumulative yield in 1000 kg.

Tapping systems in use

For exploitation of older clones RRISL had recommended the half spiral alternate, daily system of tapping (½S d/2) for the most part of their economic life (Wimalaratne, 1973) and high intensity tapping to be done 6 years before replanting (Chandrasekera 1970). Yield stimulants were recommended to be used when trees were tapped on renewed bark (Satchuthananthavale and Weerasinghe, 1973). For clones such as Gl 1, PB 28/59 which are rather sensitive to brown bast and also for clonal seedlings, half spiral, third daily system was recommended until intensification (Chandrasekera, 1970).

With the introduction of the RRIC 100 series clones, because of their high yields a cautious tentative recommendation has been given for them to be tapped for the first 3 years on ½S, d/3 and from the fourth year on ½S, d/2 ; clone RRIC 101 to be tapped on ½S, d/3 even after the third year (de Soyza, 1984; Waidyanatha *et al.*, 1984).

Response to ½S d/3 and ½S d/2 tappings

Clones RRIC 100 and 103 have responded to ½S d/3 tappings with a significantly higher yield compared to ½S d/2 tappings in their first year of tapping (Table 2).

Table 2. *Mean yield ($kg\ ha^{-1}\ y^{-1}$) and ($gt^{-1}\ t^{-1}$) in the first year of tapping*

Tapping system	RRIC 100	RRIC 101	RRIC 103
½ S d/3	1187 (32·3)	1600 (45·2)	1094 (29·7)
½ S d/2	1430 (25·8)	2390 (43·2)	1091 (19·7)

LSD (g/t/t/) = 7·5

In the second year of tapping ½S d/2 tappings have given higher yields than ½S d/3. Clone RRIC 101 responded with higher yields to ½S d/2 tappings (Table 3). However, the incidence of dry trees was much higher than the accepted limits.

Table 3. *Mean yield in ($kg\ ha^{-1}\ y^{-1}$) ($gt^{-1}\ t^{-1}$), second year of tapping*

Tapping system	RRIC 100	RRIC 101	RRIC 103
½S d/3	782 (21·3)	1171 (31·8)	880 (23·9)
½S d/2	1861 (33·6)	2204 (39·8)	1640 (29·6)

LSD (g/t/t) = 9·0

The same trend was seen in these clones when tapped on these two systems, after the third year of tapping see Table 4 (Waidyanatha *et al.*, 1984).

Table 4. *Mean yield in ($kg\ ha^{-1}\ y^{-1}$), for 3·5 years from the third year*

Tapping system	RRIC 100	RRIC 101	RRIC 103
½S d/3	1747	1269	994
½S d/2	2406	2925	1421
LSD	237	274	343

Incidence of brown bast has been negligible in RRIC 100 and 103 suggesting the possibility of tapping these two clones on d/2 frequency from the second year onwards.

Double cut systems

Tapping two panels alternatively on d/2 frequency had not resulted in higher yields than when the same panel is tapped continuously, see Table 5 (Waidyanatha *et al.*, 1984). These experiments also indicated that there was no beneficial effect on yield, when the two cuts in change over systems are separated by more than the conventional distance of 53 cm between the two cuts (Table 6). The upper cut always yielded more than the lower cut in these experiments (Table 7).

Table 5. *Mean yield (kg ha $^{-1}$ y $^{-1}$) for 3·5 years, single cuts Vs double cuts*

Tapping system	RRIC 100	RRIC 101
½S d/2	2406	2295
2 × ½S d/2 (t,t)	2052	1918
L S D	237	274

Table 6. *Mean yield (kg ha $^{-1}$ y $^{-1}$) for 3·5 years, double cut systems separation of the cuts*

Tapping system	RRIC 100	RRIC 101
2 × ½S d/2 (t,t) (53 cm)	2058	1953
2 × ½S d/2 (t,t) (106 cm)	2068	1952

Table 7. *Mean yield (kg ha $^{-1}$ y $^{-1}$), double cut systems, clone RRIC 103*

Tapping system	Mean yield for 3·5 years kg ha $^{-1}$ y $^{-1}$	
	Upper cut	Lower cut
2 × ½S 2d/3 (53 cm)	713	925
2 × ½S 2d/3 (106 cm)	733	1026

Clone RRIC 103 responded with higher yields when tapped on ½S cuts on two consecutive days and with a rest on the third day (Table 8). Here again there was no advantage in tapping 2 panels alternatively (½S, 2d/3) when compared with the same ½S cut tapped on 2 consecutive days with a rest on the third day. The separation of the cuts more than 53 cm apart also had no beneficial effect on yield (Table 9).

Table 8. *Mean yield (kg ha $^{-1}$ y $^{-1}$) for 3·5 years — double cut systems*

Tapping system		RRIC 100	RRIC 101
2 × ½S d/2 (t, t)	Upper cut	854	895
(53 cm)	Lower cut	1198	1069
2 × ½S d/2 (t, t)	Upper cut	820	920
(106 cm)	Upper cut	1248	1032

Table 9. *Mean yield (kg ha $^{-1}$ y $^{-1}$) with, separation of the cuts in double cut systems, clone RRIC 103*

Tapping system	Mean yield for 3·5 years (kg ha $^{-1}$ y $^{-1}$)	% Brown bast cuts
½S d/2	1421	nil
2 × ½S 2d/3 (53 cm)	1857	3·3
2 × ½S 2d/3 (106 cm)	1638	11·6
½S 2d/3	1769	nil
L S D	343	

Response to yield stimulation

Plugging indices of the clones calculated for ½S cuts, given in Table 10, indicate that clone RRIC 101 has a very low plugging index compared to the other clones. RRIC 101 has not responded well to ½S cuts with Ethrel stimulation (Fig. 2). RRIC 100 also did not respond well when compared with ½S d/2 tapping (Fig. 3) whereas RRIC 103 gave fairly high yields with ½S cuts with Ethrel stimulation (Fig. 4). This is of interest on account of the saving on bark consumption (Waidyanatha *et al.*, 1984).

Table 10. *Plugging indices of different clones*

Clone	Plugging index
RRIC 101	1·63
RRIM 600	2·40
RRIC 102	2·68
RRIC 100	2·68
PB 86	2·75
RRIC 103	2·92

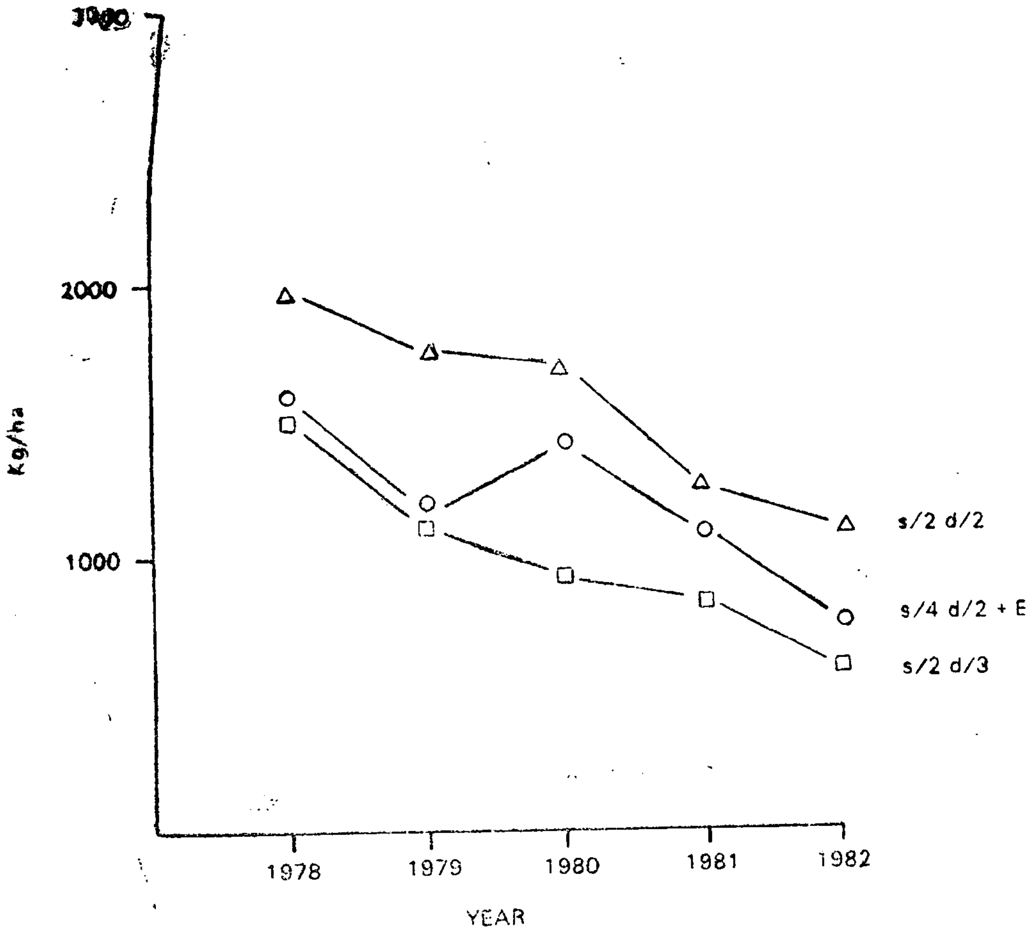


Fig. 2. Short cut vs Ethrel. Clone-RRIC 101 kg/ha.

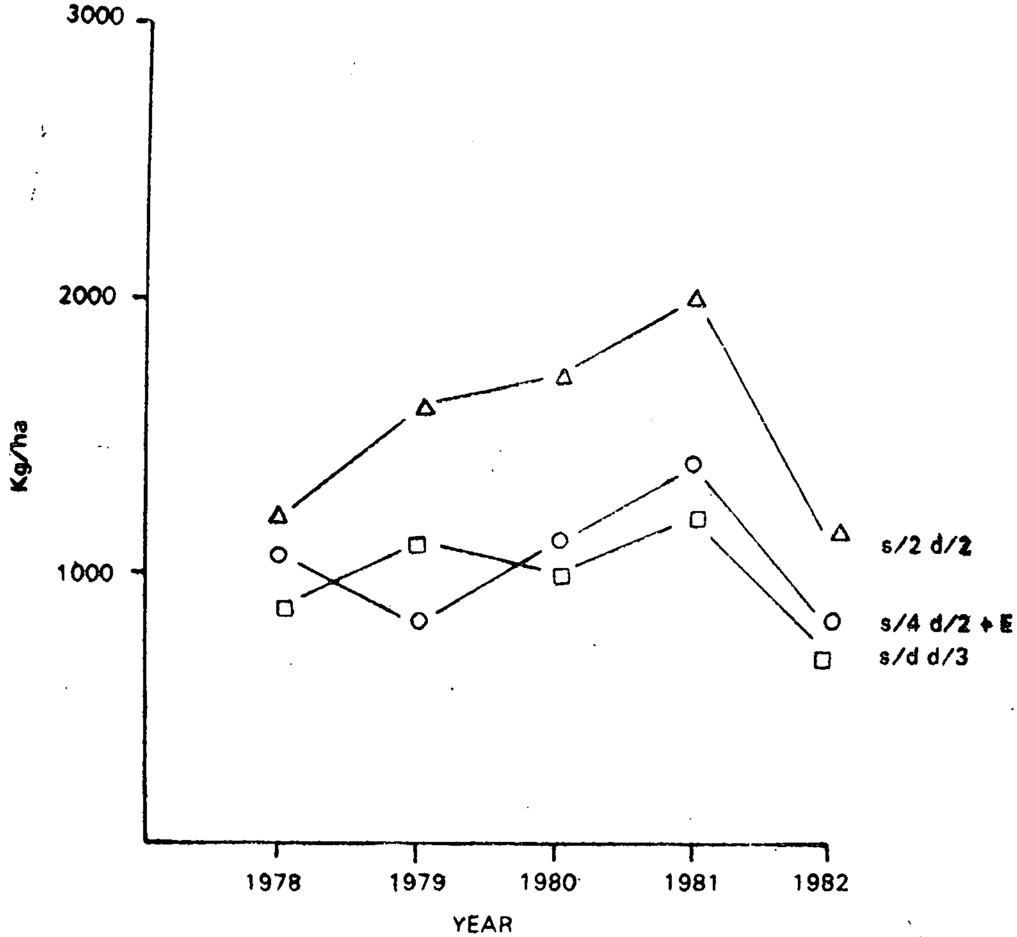


Fig. 3. Short cut + Ethrel vs conventional systems. Clone-RRIC 100.

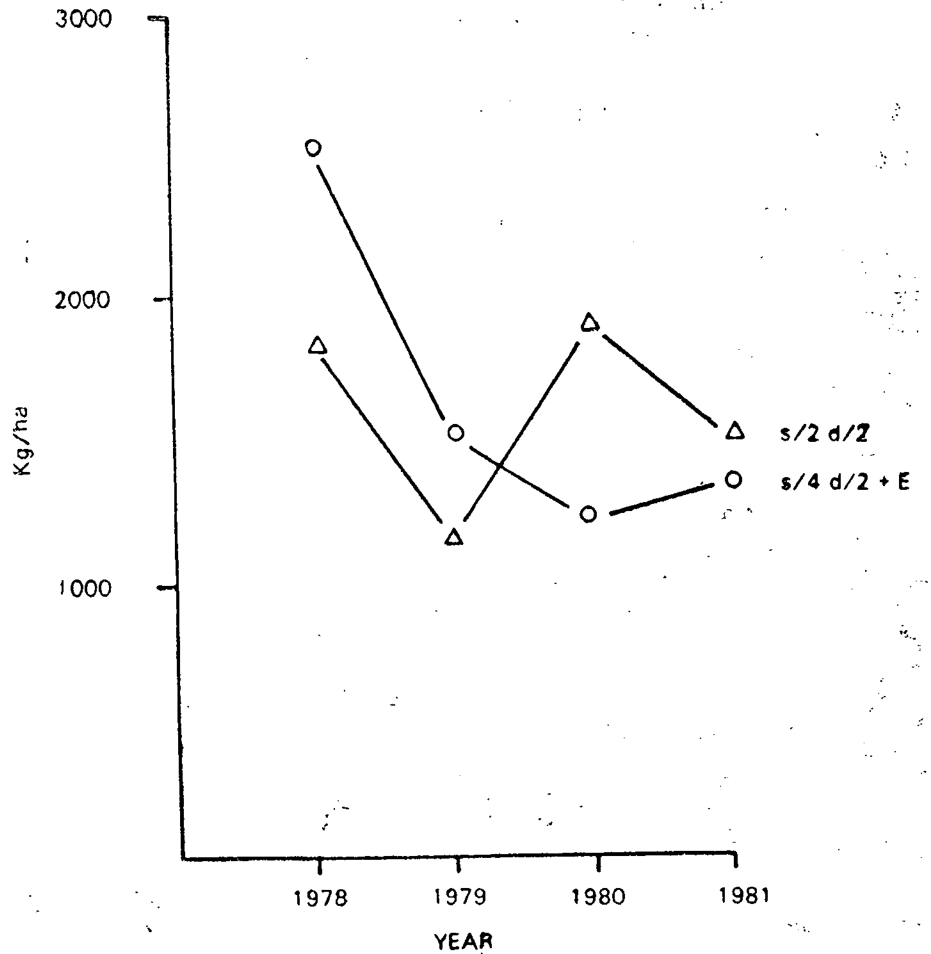


Fig. 4. Short cut + Ethrel vs conventional systems. Clone-RRIC 103.

Response to puncture tapping

Puncture tapping on a 1 m vertical band with six punctures on d/2 frequency has given yields far below that of conventional cut tappings in clone RRIC 100 (Fig. 5); whereas RRIC 101 gave yields comparable with ½S d/2 tappings (Fig. 6). The incidence of brown bast also has been very low in this experiment (Waidyanatha *et al*, 1984). This is of great interest as this clone is very prone to brown bast with conventional cut tappings. Clone RRIC 103 did not respond well to puncture tapping. A 2 meter vertical band with 12 punctures on d/2 frequency has given yields comparable to ½S d/2 tappings (Fig. 7). However, the brown bast incidence has been rather high in clone RRIC 103 with this system of tapping (Waidyanatha *et al.*, 1984).

DISCUSSION

Most clones respond well to ½S d/3 and ½S d/2, tappings, as selection of clones is done with these tapping systems. However, these experiments indicate that certain clones respond well to tapping systems other than the conventional systems that are in use. Clone RRIC 101, which is prone to brown bast with conventional cut tappings, gave economic yields with puncture tapping on a 1 m vertical band. Clone RRIC 103 has responded well to relative tapping intensities, higher than those that are in use. This clone also responded with high yields to stimulated ¼S cuts. Further experiments are in progress to evaluate suitable tapping systems for different clones under different agroclimatic regions.

ACKNOWLEDGEMENT

Our thanks are due to Mr W. N. Wickremasinghe, Biometrician, for the statistical analysis of the data and the staff of the Plant Science Department for their assistance in carrying out the experiments discussed.

REFERENCES

CHANDRASEKERA, L. B. (1973). Recommended planting material 1973, *Bul. Rubb. Res. Ins. Sri Lanka* **7**, 85—93.

CHANDRASEKERA, L. B. (1970). Tapping of *Hevea* rubber, *Handbook of Rubber Culture and Processing*, 36—45, Ed. O. S. Peries, Sri Lanka : RRI.

DE SOYSA, A. G. A. (1984). Exploitation of rubber trees, *Handbook of Rubber Culture and Processing*, 31—65. Eds. O. S. Peries and D. M. Fernando, Sri Lanka : RRI.

JAYASEKERA, N. E. M. AND FERNANDO, D. M. (1981). New RRIC 100 series clones recommended for planting, *Bul. Rub. Res. Ins. Sri Lanka.* **16**, 23—26.

JAYASEKERA, N. E. M. AND FERNANDO, D. M. (1984). RRIC 100 series clones recommended for planting, *Practical Guide to Rubber Planting and Processing*. Eds. A. de S. Liyanage and O. S. Peries, Sri Lanka : RRI.

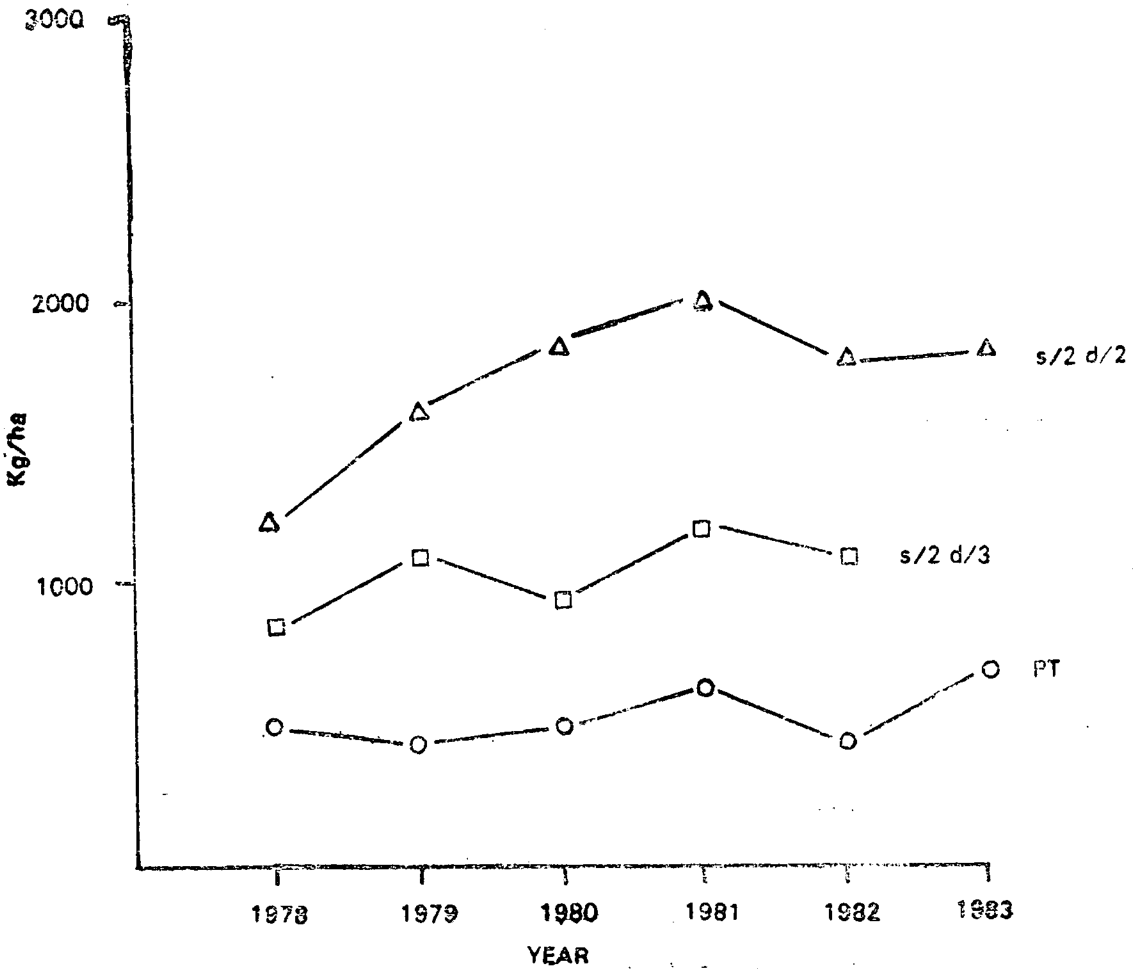


Fig. 5. Puncture tapping vs conventional tapping. Clone-RRIC 100

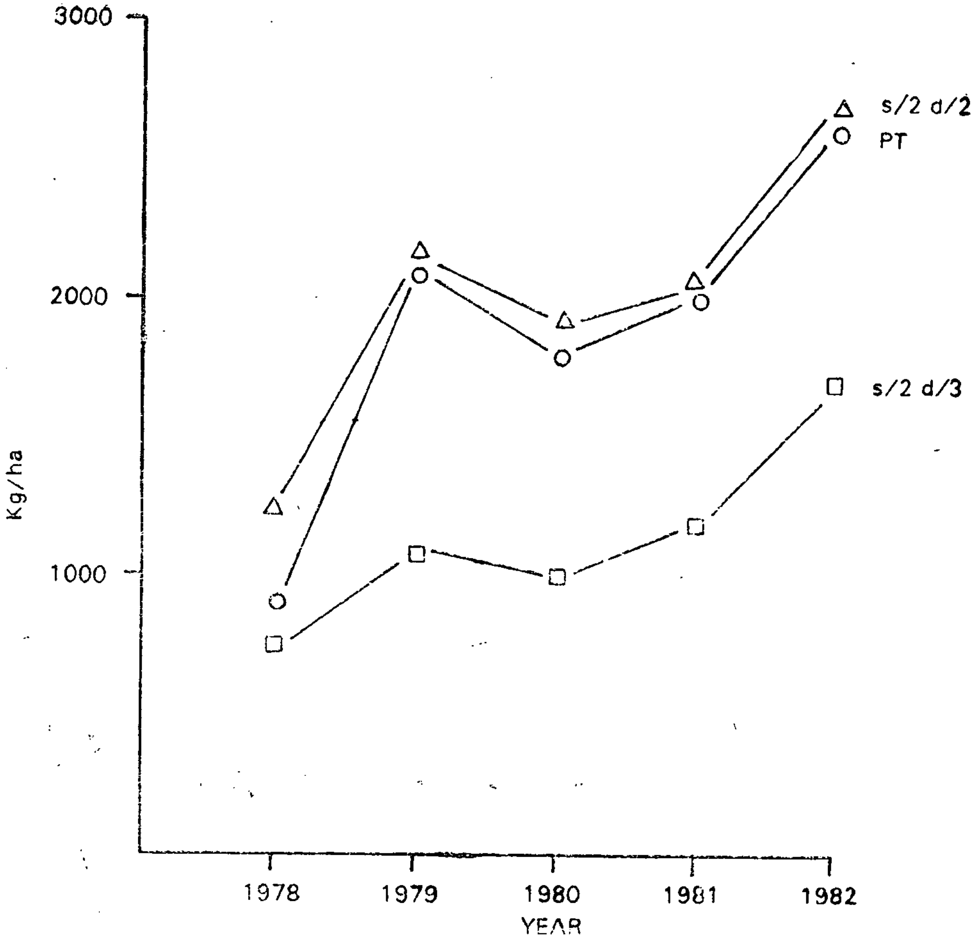


Fig. 6. Puncture tapping vs conventional tapping. Clone-101

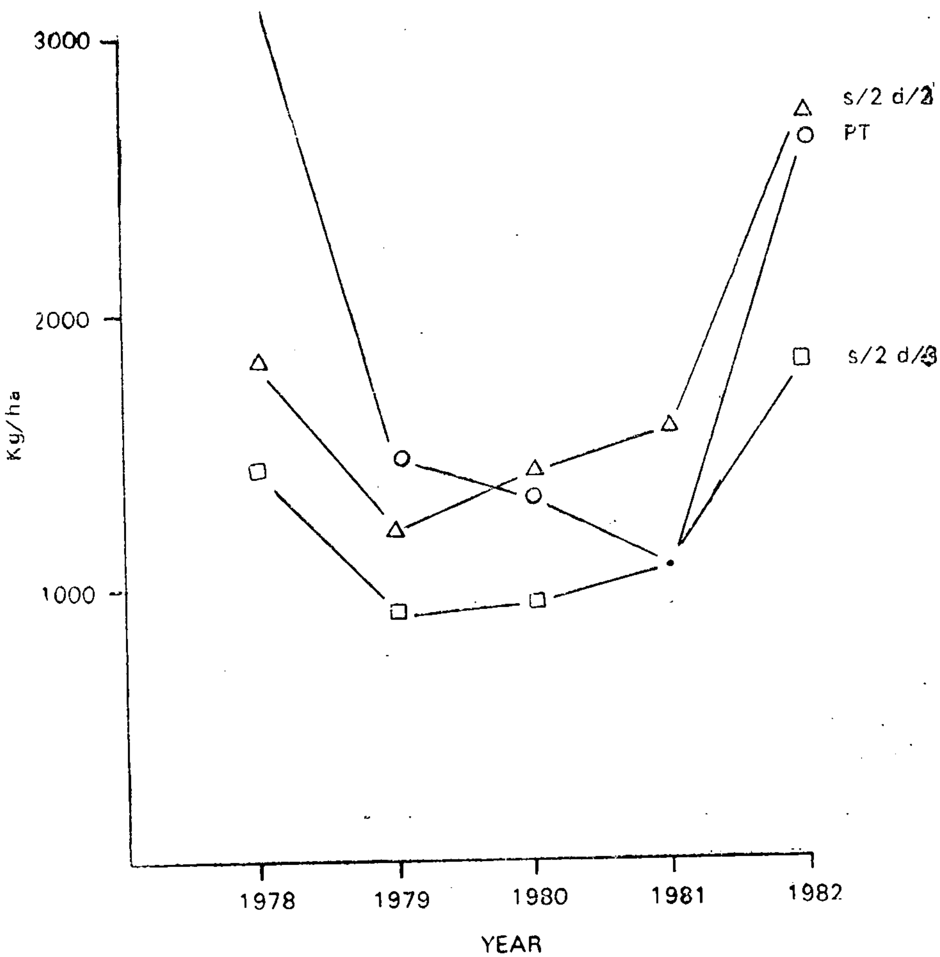


Fig. 7 Puncture tapping vs conventional tapping. Clone-103

SATCHUTHANANTHAVALE, R. AND WEERASINGHE, T. C. (1977). Ethrel stimulation of *Hevea* under condition in Sri Lanka. *J. Rubb. Res. Inst. Sri Lanka* **54**, 150 — 162.

WAIDYANATHA, U. P. DE S., SAMARANAYAKE CHANDRA, DE SOYZA, A. G. A. AND PERERA, M. C. (1983). Virgin bark tapping of RRIC 100, RRIC 101 and RRIC 103. *J. Rubb. Res. Inst. Sri Lanka.* **61**, 17 – 24.

WIMALARATNE, S. D. (1973). Economic evaluation of tapping systems. *Q. Jl. Rub. Res. Inst. Sri Lanka* **50**, 40 — 54.

DISCUSSION

Q — ANON : In your studies I was able to see a big difference between half spiral d/2 and half spiral d/3. I can understand that the yield per ha is bigger in d/2 than d/3. The question now is how can yield per tapper/tree be so high in d/2 in comparison to d/3. Is it special for these clones or have you observed this in other clones too.

A — A. C. I. SAMARANAYAKE, (RRISL) : No, same trend was seen for clones such as PB 86 too.

Q — D. C. BARLOW (Australia) : Any other problem which occurred with PT other than what you mentioned.

A — A. C. I. SAMARANAYAKE, (RRISL) : We had no problem except for low yield. We had brown bast only in 2 m band.

Session 4. FERTILIZER USE

RECENT DEVELOPMENTS IN THE NUTRITION OF *HEVEA* IN SRI LANKA

By

N. YOGARATNAM, F. P. W. SILVA AND S. M. WEERASURIYA
(Rubber Research Institute, Sri Lanka, Agalawatta.)

ABSTRACT

The fertilizer policies and practices during early growth and the subsequent mature phase in Hevea *replantings are discussed. Based on the recent results and on the review of earlier work, general recommendations for fertilizer use are offered.*

Applications of N, P and K fertilizers in the form of urea, rock phosphate and muriate of potash were effective in increasing the leaf N, P and K concentrations, respectively, of immature Hevea *cultivars, PB 86, RRIC 100, RRIC 101 and RRIC 102. These responses have been due to each nutrient acting separately. The lag between fertilizer application and changes in their respective leaf nutrient concentration was longer for P than N and K. Fertilization with urea at levels varying from 190 to 310 kg of N, rock phosphate at 100 to 160 kg P and muriate of potash at 190 to 310 kg K per ha has also been shown to be an efficient and practical method of increasing the vigour of immature PB 86, RRIC 100, 101 and 102. Increasing the levels of nutrients beyond these levels is not likely to give any additional benefit, except with nitrogen under a mixed growth of naturals and legumes. In such instances the level of N could be increased to approximately 380 to 620 kg N/ha. Fertilization with NPK can reduce the unproductive period of RRIC 100 series clones by about 18 to 24 months in comparison with PB 86.*

Results of a series of field experiments on fertilizer responses in mature rubber indicated that yield increases in the existing plantations could be obtained with increased applications of nitrogen in the form of urea. Applications of K fertilizers may give yield increases in some cases but P and Mg applications can be discontinued for several years if these fertilizers had been applied regularly during the immature phase.

Urea can be effectively used as the only source of N throughout the immature and mature periods.

INTRODUCTION

In rubber plantations with monocultural cropping system, it had been the practice to use the same nutrients more or less in the same proportion over the last several years (Fig. 1). This practice is likely to cause imbalances in the available nutrients possibly due to depletion or accumulation of nutrients. Moreover, there is considerable variability in the physical and chemical characteristics of soils under rubber in Sri Lanka and these two factors and their interaction may also influence the performance of *Hevea*.

A series of experiments were therefore started in order to re-examine and further ascertain and quantify the nutrient needs of *Hevea*. This paper attempts to summarise the recent developments and based on these the fertilizer policies and practices for *Hevea* plantations in Sri Lanka are discussed.

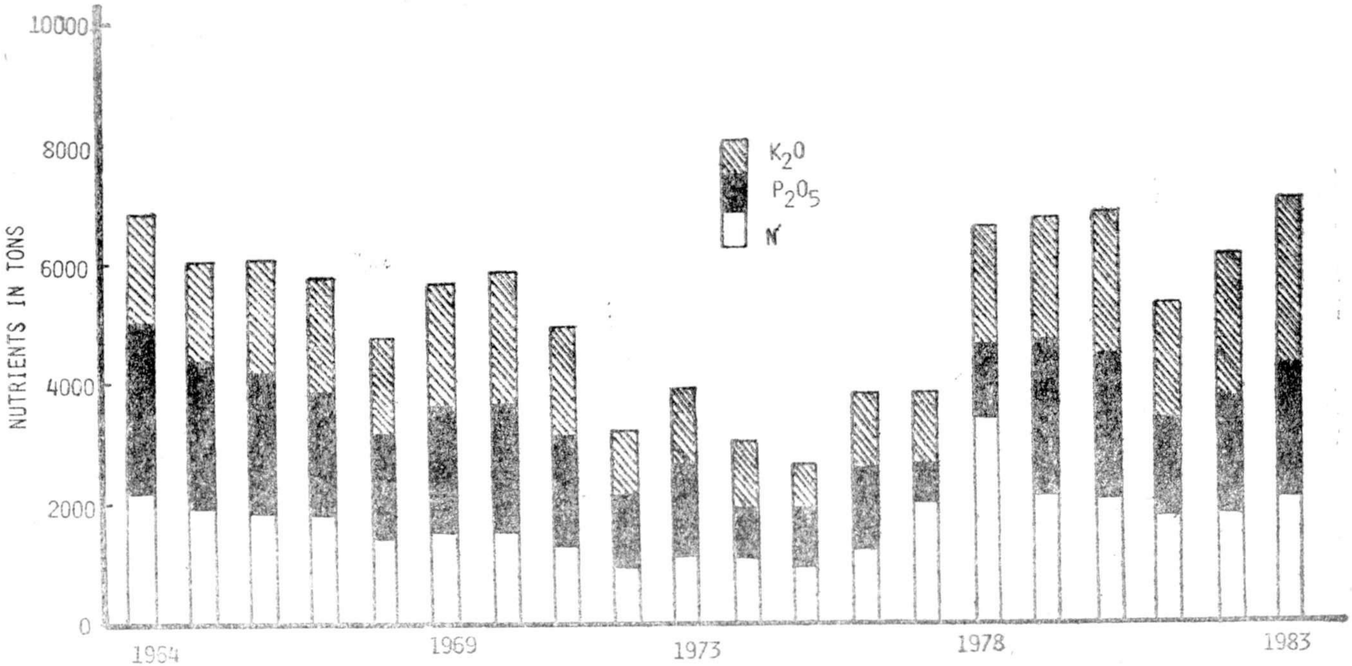


Fig. 1. **Fertilizer use ($N - P_2O_5 - K_2O$) 1964 - 1983**

MATERIALS AND METHODS

Immature *Hevea*

Details of three experiments on immature *Hevea* cultivars are discussed. The main objectives of the experiments were as follows :

Experiment 1

The effects of three levels of nitrogen and potassium were compared on clones PB 86 (control), RRIC 100, RRIC 101 and RRIC 102 in Homagama series soils (quartzitic). These four clones formed the main plot treatments with three levels of nitrogen — 0, 310 and 620 kg N/ha as urea and potassium — 0, 310 and 620 kg K/ha as potassium chloride (muriate of potash) in the sub-plots, in a split plot design with two replicates. The experimental trees were planted in June/July 1976 and grown with a mixed leguminous cover of *Pueraria phaseoloides* and *Desmodium ovalifolium*. All plants received uniform applications of 160 kg P/ha as rock phosphate and 65 kg Mg/ha as kieserite during the full immature period.

Experiment 2

In this experiment the effects of three levels of nitrogen (as in Experiment 1) and phosphorus — 0, 160 and 320 kg P/ha as rock phosphate were compared on clones PB 86, RRIC 101 and RRIC 102 in Agalawatta series soils (granite derived). The ground cover consisted of a mixed growth of legumes and naturals. All trees received uniform applications of 310 kg N/ha as urea and 65 kg Mg/ha as kieserite.

Experiment 3

Effects of three levels of potassium (identical to Experiment 1) on the performance of clones PB 86, RRIC 100 and RRIC 101 in *Boralu series* soils (overlying cabook) with a mixed leguminous cover of *Pueraria* and *Desmodium* were studied in this experiment. Uniform applications of N, P and Mg were given to all experimental trees at the rate of 310 kg N, 160 kg P and 165 kg of Mg per hectare during the immature period.

Records

Growth assessments were made by measuring trunk girths annually from November/December 1978 at a constant height of 120 cm above the union on all effective trees. Diameter and girth measurements were also made every 6 months since planting until December 1978 at lower heights, varying from 35 to 70 cm.

Tappability of trees was evaluated by recording the total number of trees that had attained a standard girth of 50 cm at a height of 120 cm and expressed as a percentage in relation to the total number of recording trees in each plot.

RESULTS

Routine analyses done to characterise the soil (Table 1) appear to indicate that, the pH and total N at all sites were satisfactory, but available P, K and Mg status varied between experiments.

Table 1. *Routine soil analyses.*

Experiment — soil — sampling depth

Characteristics	Experiment 1 Homagama (quartzitic) 0 - 15 (cm)	15 - 30 (cm)	Experiment 2 Agalawatta (granatic) 0 - 15 (cm)	15 - 30 (cm)	Experiment 3 Boralu (cabook) 0 -15 (cm)	15 - 30 (cm)
pH (water)	4·15	4·20	4·30	4·15	4·70	4·50
C (%)	1·86	0·97	2·22	1·24	2·12	0·76
N (%)	0·24	0·13	0·25	0·16	0·24	0·13
Total — P (ppm)	353	273	337	202	248	183
Available - P (ppm)	17·0	2·0	42·5	4·5	13·3	2·0
Total — K (me/100g)	3·33	3·21	3·01	3·33	3·43	3·46
Total — Mg (me/100g)	5·99	6·61	5·12	5·26	3·51	4·23
Exchangeable — K (me/100g)	0·12	0·04	0·07	0·05	0·07	0·02
Exchangeable — Mg (me/100g)	0·15	0·03	0·16	0·05	0·15	0·05
CEC (me/100g)	5·67	4·64	5·95	4·26	4·99	3·66

Total P by perchloric/sulphuric acid; available P by NH_4F/HCl; total K and Mg by 6 N HCl and exchangeable K and Mg and CEC by ammonium acetate at pH 7.

The yearly mean girth commencing at 30 months after planting up to the time the trees were marked for latex collection (tapping), girth increment during this period and the percentage tappability towards the end of the immature period are given in Tables 2 to 5 and Figs. 2 to 9. Only the yearly mean girth and logarithmic transformations of trunk girth increases were subjected to analysis of variance. For convenience, untransformed values are presented and covariance analysis was also considered unnecessary as any girth difference recorded 30 months after planting would have been a reflection of the experimental treatment effects.

Nitrogen

Girths in Experiment 1 (Table 2) were increased in all cultivars from 1978 with N fertilization at level 1 although these effects were significant ($P < 0{\cdot}05$ and $0{\cdot}001$) only from 1979. Further increase in the level of nitrogen to N_2 did not give much additional increases. On the other hand in Experiment 2, the increases in girth with the highest level of nitrogen were more marked with increases in the region of 18% over the no nitrogen control. Final girth (Fig. 2) was higher by only 4 and 5% over the control in the N_1 and N_2 treated trees, respectively, in Experiment 1, and by 6 and 14% with N_2 levels respectively, in Experiment 2.

Table 2. *Effect of nitrogen fertilization on girth and girth increment (cm)*

Treatment	Girth 1978	1979	1980	1981	1982	Increment (1978 to 1983)
	Experiment 1					
N_0	15·84	20·89	28·31	37·70	46·22	33·68
N_1	16·48	23·22	31·09***	40·97***	49·19***	35·05*
N_2	16·94	23·43*	31·66***	42·24***	50·57***	35·36*
	Experiment 2					
N_0	15·75	20·38	27·80	37·38	43·59	31·75
N_1	16·56	21·65	29·53	39·02	46·77	33·64*
N_2	16·74	23·87*	32·40*	43·78**	51·36**	37·56**

Girth increment data (Table 2) indicating the rate of growth of all cultivars over the last 5 year period of immaturity in Experiment 1 showed that with N_1 and N_2 levels of nitrogen the growth rate had been higher ($P < 0{\cdot}05$) by 1·37 and 1·68 cm, respectively, over the control, compared to still higher rates of 1·89 and 5·81 cm with N_1 ($P < 0{\cdot}05$) and N_2 levels ($P < 0{\cdot}01$) in Experiment 2.

Percentage tappability of trees at the end of 5, 6 and 7 years (60, 72 and 84 months) from planting are presented for convenience, in Figs. 3 and 4 as calculations before the 5-year period is not likely to give any meaningful information. It is evident that the attainment of tappable standard closely followed the response of girth in both Experimental and 2. A closer scrutiny indicated that, in general, RRIC 100 series clones reached the tappable stand much earlier than PB 86. With PB 86, it was still not possible to attain

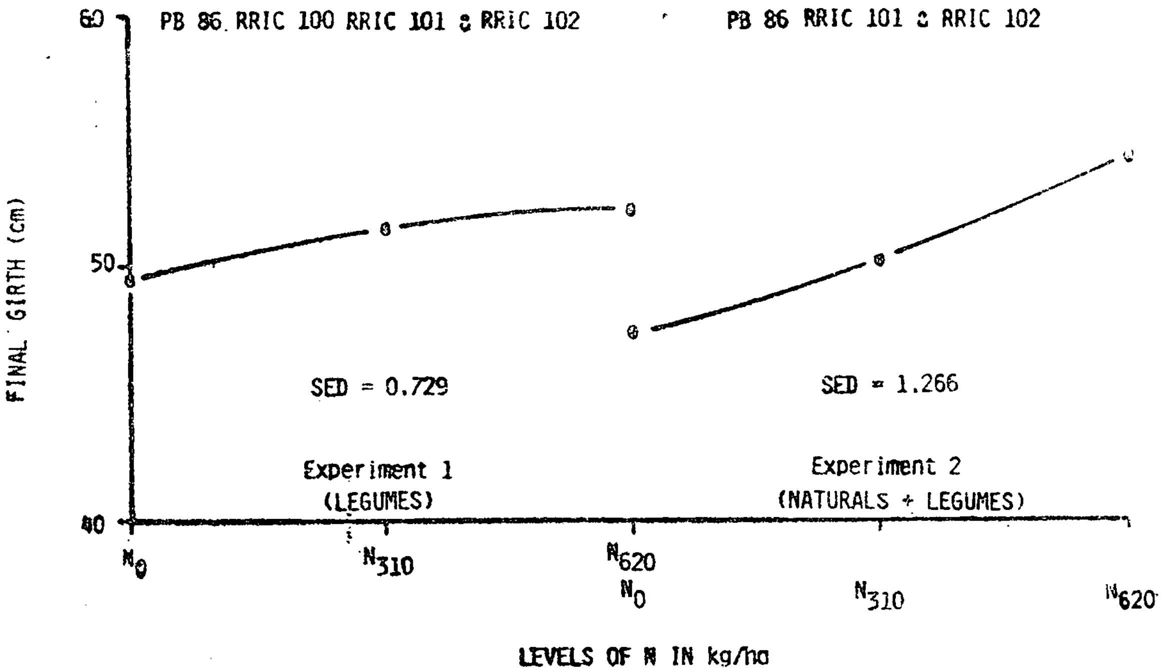


Fig. 2. Effect of nitrogen fertilization on final girth.

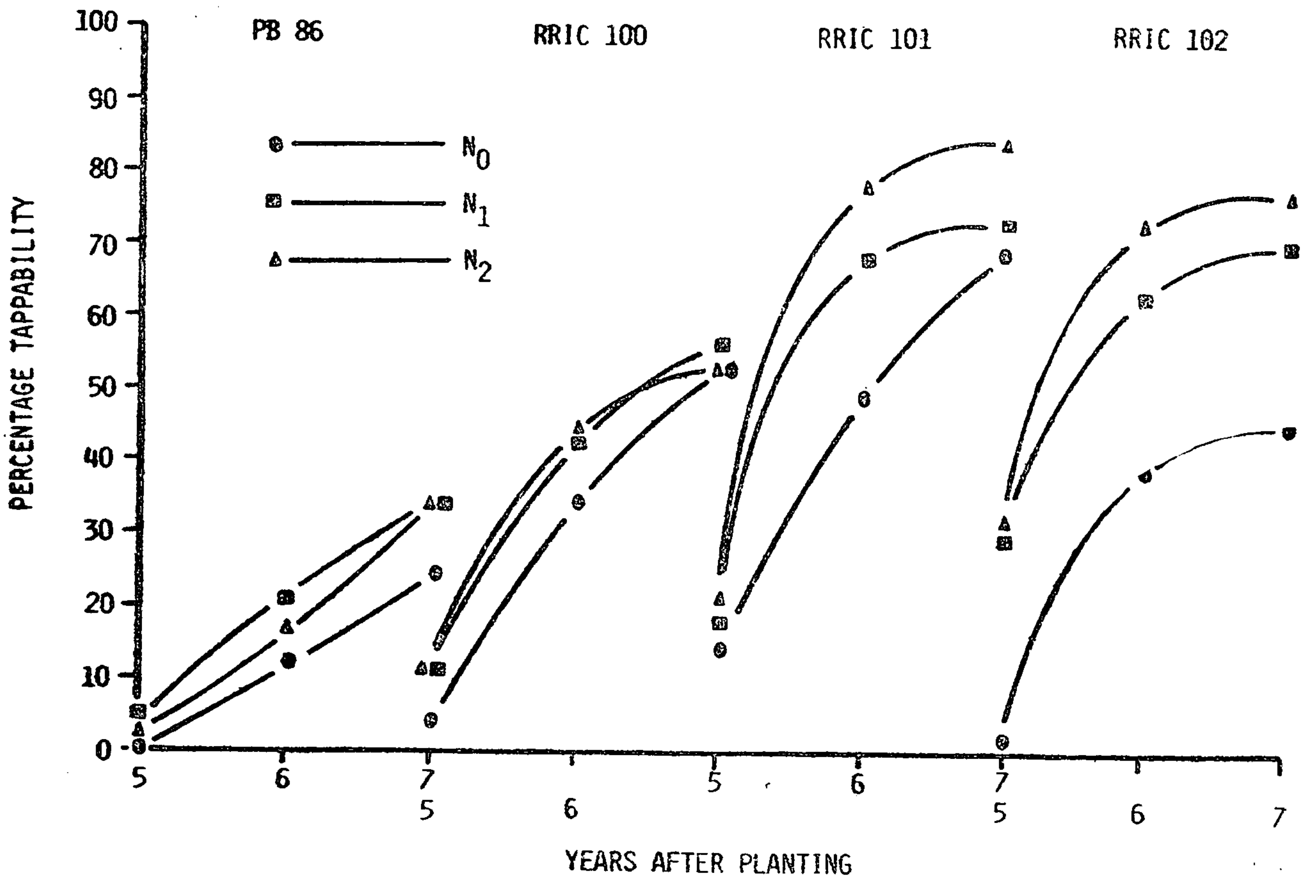


Fig. 3. Effect of nitrogen fertilization on percentage tappability of PB 86, RRIC 100, RRIC 101, and RRIC 102.

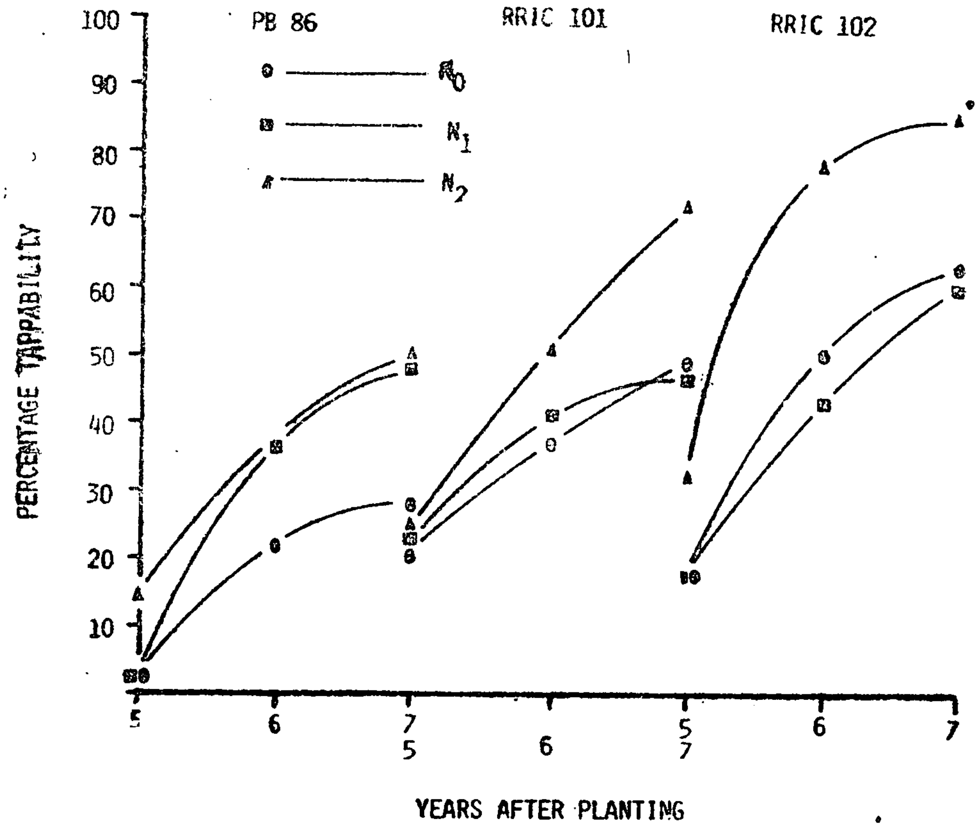


Fig. 4. Effect of nitrogen fertilization on percentage tappability of PB 86, RRIC 101 and RRIC 102.

50% tappability at the end of 84 months with even the highest level of N, in Experiment 1. On the other hand clone RRIC 100 reached the tappable standard in about 81 months with no nitrogen and this was advanced to about 75 months with nitrogen at N_1 and N_2 levels.

It was also possible to achieve tappability in approximately 72, 66 and 63 months with N_0, N_1, and N_2 levels of nitrogen, respectively, in both clones RRIC 101 and RRIC 102 except at N_0 level by RRIC 102. In Experiment 2, PB 86 reached tappable girth with the N_2 level at the end of 84 months, whereas RRIC 101 and RRIC 102 reached the same level in just 72 and 63 months, respectively. Reduction in the level of nitrogen to N_1 resulted in the extension of the unproductive period by approximately 12 months in RRIC 101 and 102.

Phosphorus

Fertilization with P at level 1 significantly increased ($P < 0{\cdot}05$) trunk girth of all clones in 1980 (Table 3) and no further increase was obtained with the P_2 level. Similar and consistent effects were also observed thereafter ($P < 0{\cdot}05$) in all cases except $P < 0{\cdot}01$ in 1982 with P_2 level of phosphate). The final girth of 53·0 cm with the P_2 level (Fig. 5) prior to the commencement of tapping, indicated a 12% increase ($P < 0{\cdot}01$) over the no phosphate control.

Table 3. *Effect of phosphate fertilization on annual girth and girth increment Experiment 2 (cm)*

Treatment	Girth 1978	1979	1980	1981	1982	Increment (1978 to 1983)
P_0	16·33	21·34	28·34	36·40	44·13	31·37
P_1	16·08	22·05	30·58*	40·81*	47·56*	35·22*
P_2	16·66	22·49	31·87*	42·97*	50·02**	36·34*

Girth increment in all cultivars in response to phosphate application has also been significantly higher ($P < 0{\cdot}05$) by 3·85 and 4·97 cm with P_1 and P_2 levels, respectively. Relative to no phosphate application, this means a percentage increase of 12 and 16 for P_1 and P_2 levels, respectively.

In general, the tappability levels were reached in clones RRIC 101 and 102 earlier than in PB 86 (Fig. 6). Phosphate application at the P_1 level made it possible for PB 86 to be tapped in 84 months and the P_2 level in 78 months *i.e.* 6 months earlier. In the absence of P fertilizers it was possible to attain only 30% tappability at the end of 84 months (7 years). In clone RRIC 100, latex production could have commenced in 84, 78 and 72 months with phosphate at P_0, P_1 and P_2 levels, respectively. More reductions were achieved in RRIC 102 where production could have commenced in 72 and 67 months with P_0, P_1 and P_2 levels, respectively.

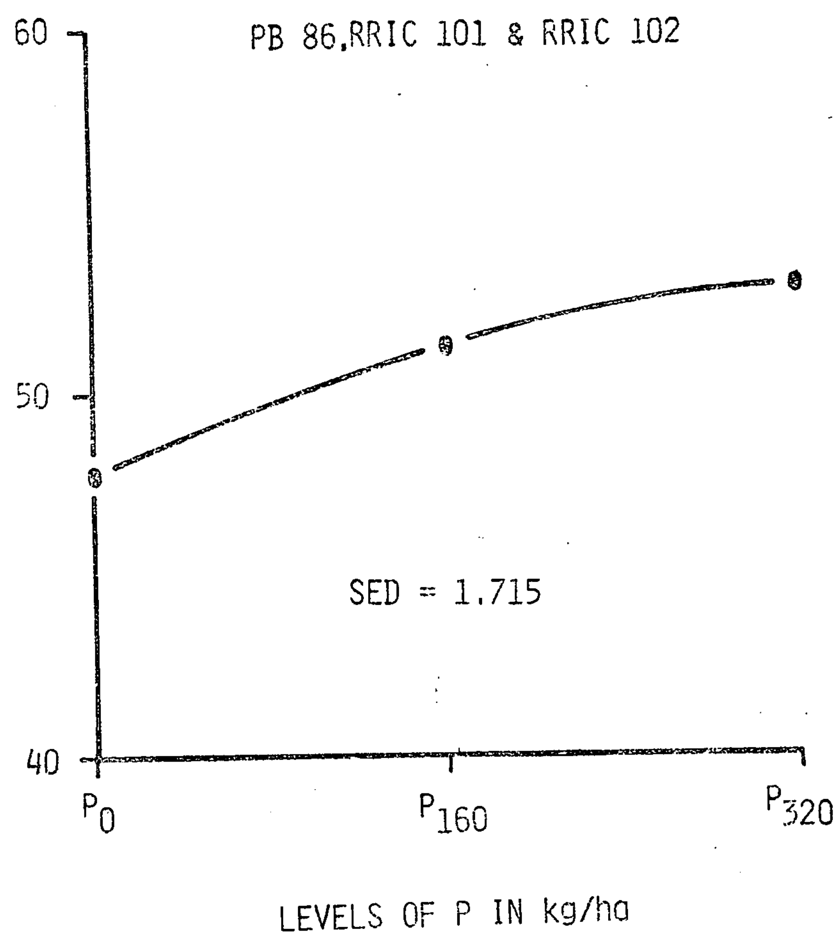


Fig. 5. Effect of phosphorus fertilization on final girth.

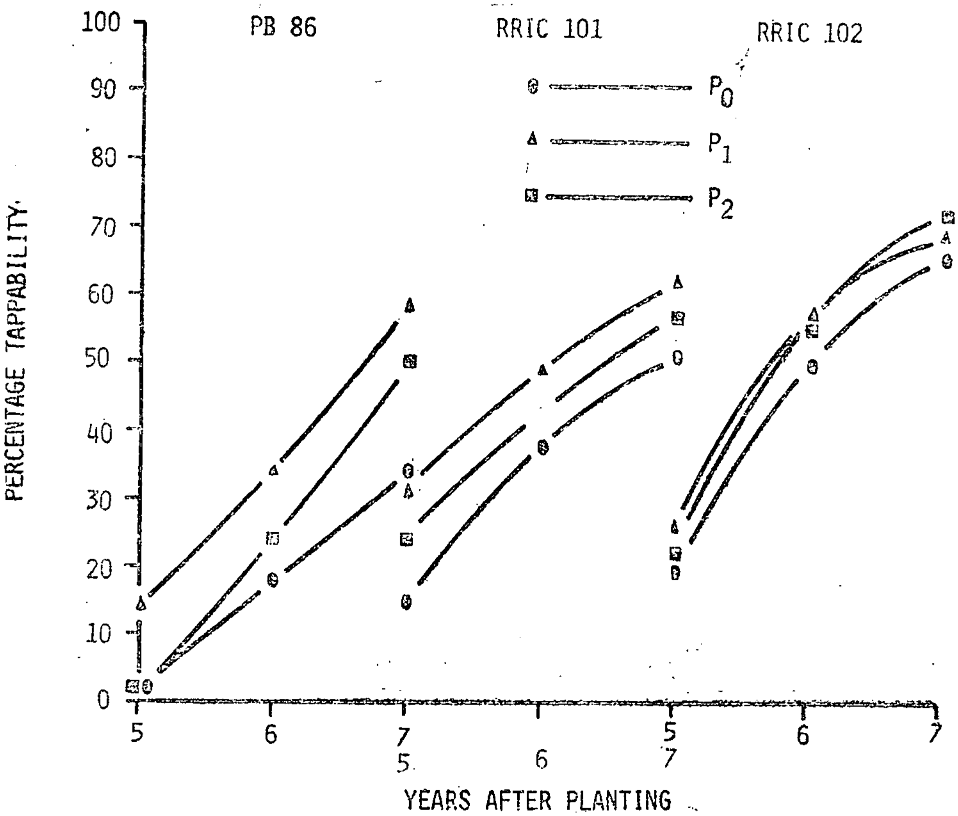


Fig. 6. Effect of phosphorus fertilization on percentage tappability of PB 86, RRIC 101 and RRIC 102.

Potassium

Girthing responses to K were evident in all cultivars in both Experiment 1 and 3 (Table 4) and this effect was fairly large and consistent throughout the immature period. Girth increases were significant from 1978 at $P < 0 \cdot 05$ in 1978 and 1979 and $P < 0 \cdot 001$ in 1980 to 1982 in Experiment 1 and at $P < 0 \cdot 05$ in 1978 and 1981 and $P < 0 \cdot 001$, in 1979, 1980 and 1982 in Experiment 3 at both K_1 and K_2 levels. It would be pertinent to mention that diameter measurements at 8 months intervals, recorded from the time of planting in Experiment 3 (not presented), also increased significantly ($P < 0 \cdot 01$ in December 1976 and $P < 0 \cdot 001$ in July and December 1977), in response to K fertilization at both K_1 and K_2 levels. Final girth in Experiment 1 (Fig. 7) showed similar responses in all cultivars with an average 15% and 18% increases ($P < 0 \cdot 001$) for K fertilization at K_1 and K_2 levels, respectively. On the other hand, a significant interaction was evident in Experiment 2, suggesting that in the absence of K fertilizers there had been no differences in girth between cultivars but with K fertilization, girth in RRIC 101 was significantly ($P < 0 \cdot 05$) higher than in PB 86 and RRIC 100.

Table 4. *Effect of potassium fertilization on girth and girth increment (cm)*

Treatment	Girth 1978	1979	1980	1981	1982	Increment (1978 to 1983)
	Experiment 1					
K_0	14·98	19·56	27·23	36·86	43·98	31·85
K_1	16·89*	23·84*	31·76***	41·55***	50·56***	36·16**
K_2	17·19*	24·14*	32·11***	42·55***	51·43***	37·07**
	Experiment 3					
K_0	17·93	22·52	31·84	39·30	44·14	29·57
K_1	20·64*	25·03***	35·35***	43·30*	49·03***	33·66**
K_2	21·03*	26·62***	36·74	44·81*	49·66***	34·07**

Increment in girth had been influenced by K fertilization (Table 4) in both Experiments 1 and 3 as expected. Percentage increases of 16 and 19 in Experiment 1, and 14 and 15 in Experiment 3, were recorded over controls with K_1 and K_2 levels respectively in each experiment.

PB 86 never attained the tappable stand in either experiment (Figs. 8 and 9) except with the K_2 level in Experiment 3, after 84 months. It was, however, possible to shorten the unproductive period in RRIC 100 to about 70 months with either the K_1 or K_2 levels and approximately 60 months in both RRIC 101 and 102 with the K_1 level in both experiments. Increased level of fertilization at K_2 did not show any further reduction in the unproductive period in either experiment.

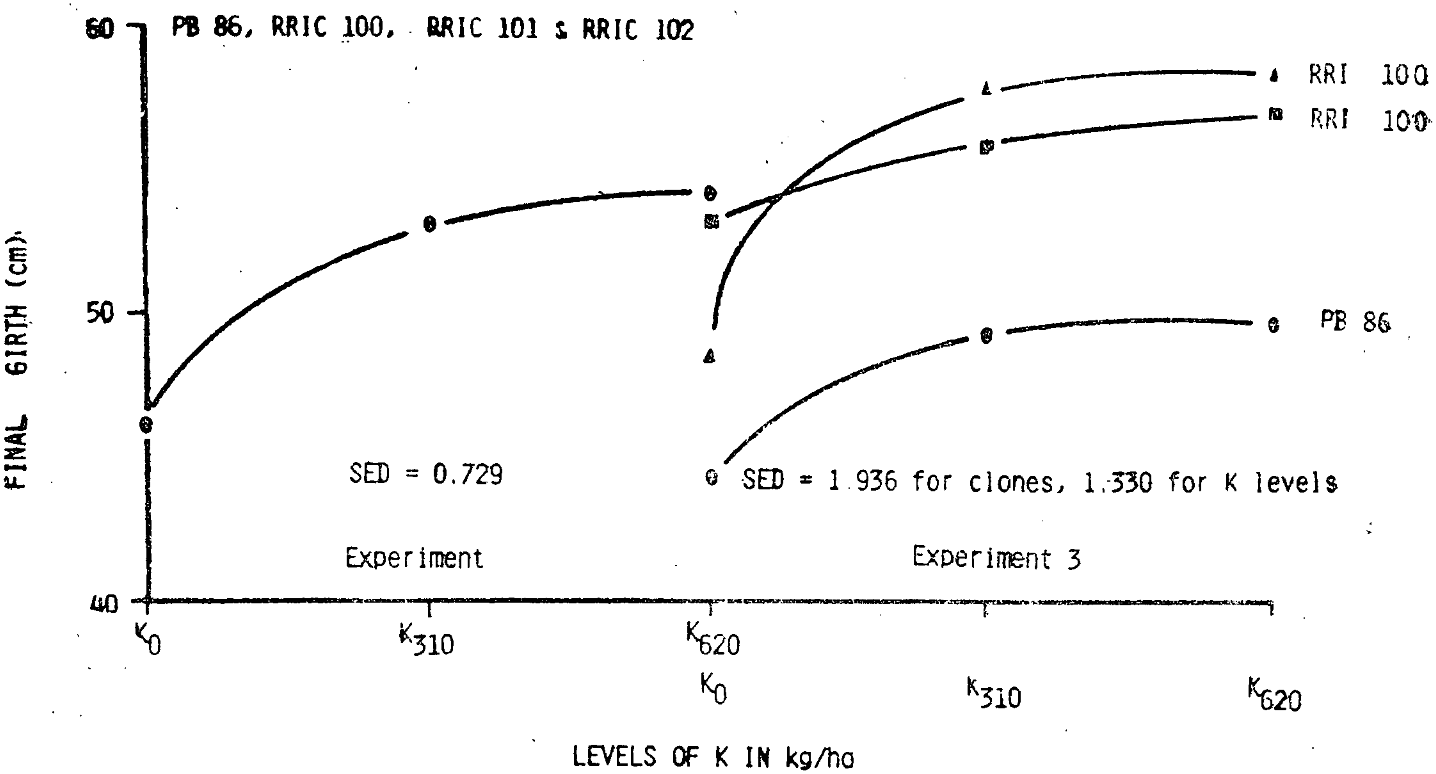


Fig. 7. **Effect of potassium fertilization on final girth.**

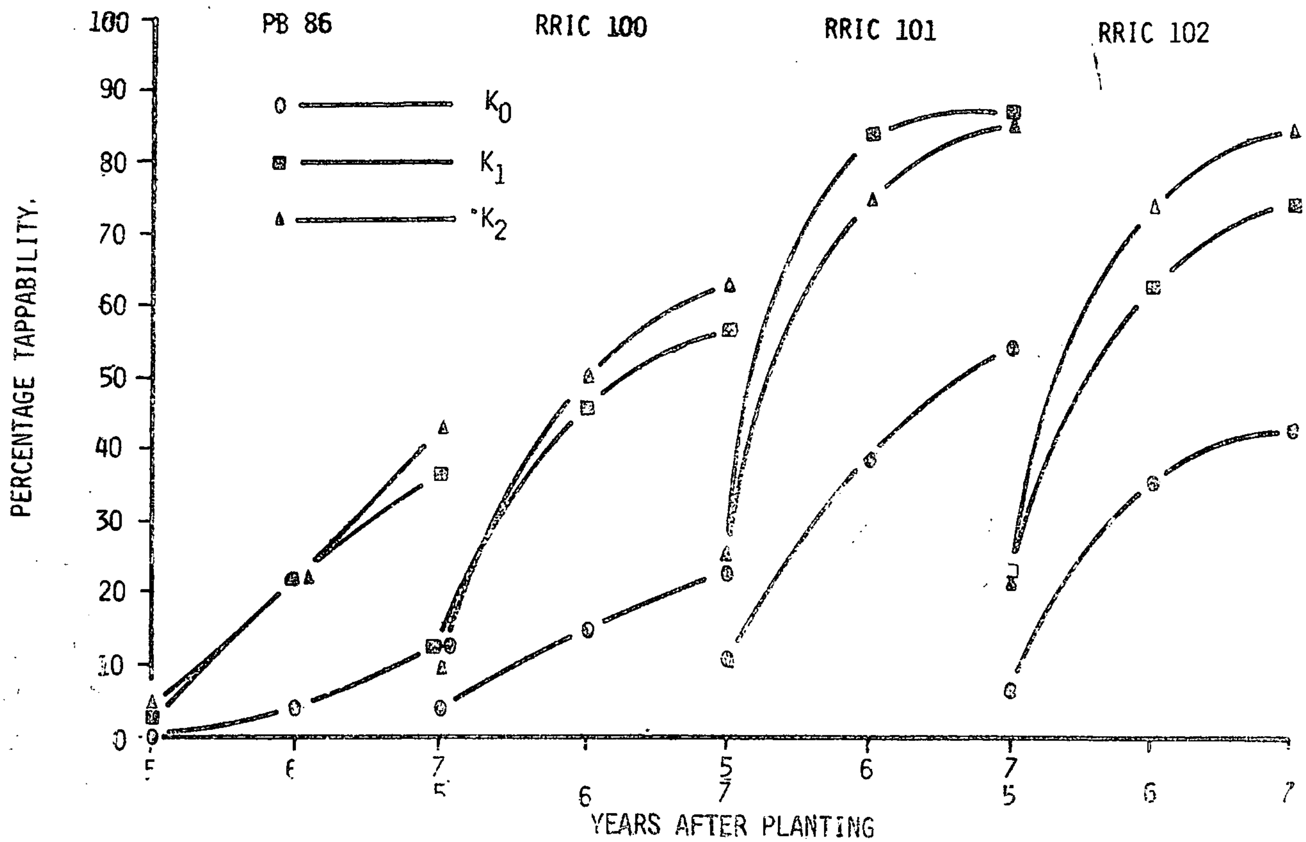


Fig. 8. Effect of potassium fertilization on percentage tappability of PB 86, RRIC 100, RRIC 101 and RRIC 102.

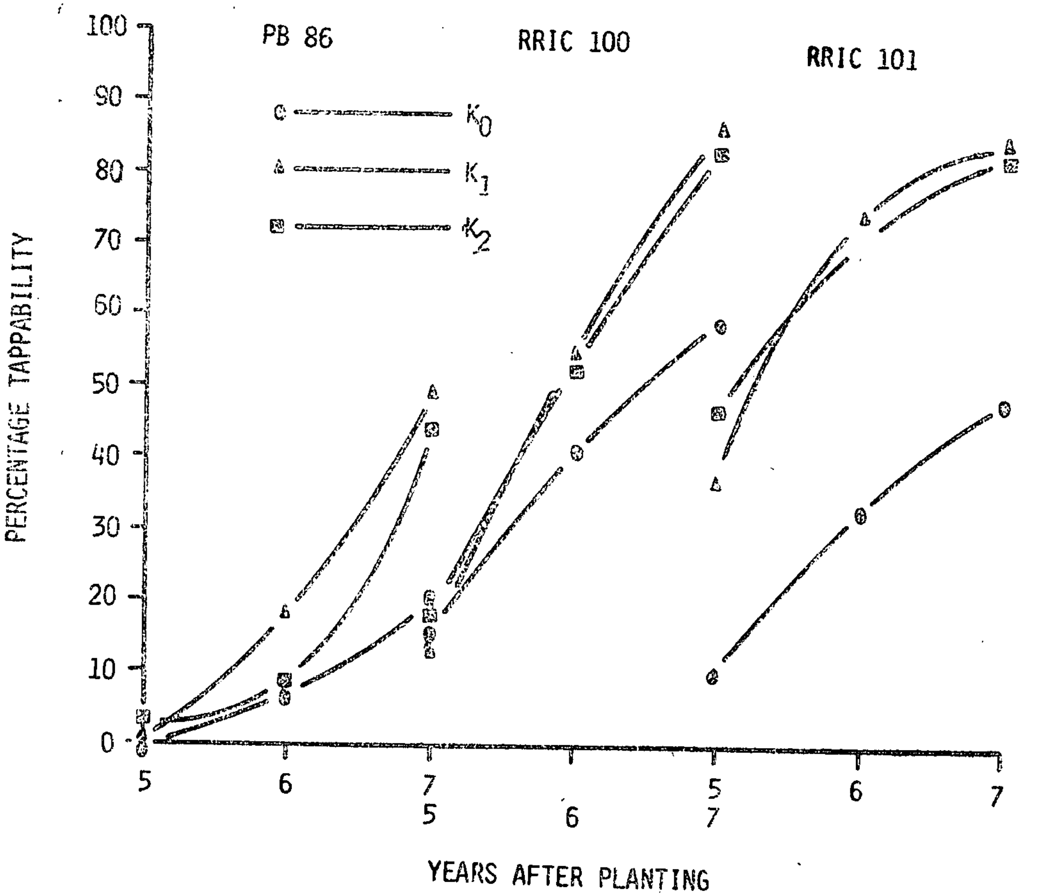


Fig. 9. Effect of potassium fertilization on percentage tappability of PB 86, RRIC 100 and RRIC 101.

Although individual clones showed some variations in their effects (Table 5) there were no significant interactions between treatments on either girth or girth increments in any of the Experiments, except for levels of K and different cultivars (Experiment 3, already presented).

Table 5. *Annual girth and girth increment in immature PB 86, RRIC 100, 101 and 102 (cm)*

Cultivars	Girth 1978	1979	1980	1981	1982	1983	Increment (1978 to 1983)
	Experiment 1						
PB 86	14·66	18·48	27·67	35·80	42·79	46·10	31·44
RRIC 100	15·84	22·62	30·30	39·89	48·44	50·80	34·96
RRIC 101	16·98	23·74	31·93	43·47	51·93	54·8	37·82
RRIC 102	17·04	24·08	32·36	42·09	51·47	53·6	36·56
	Experiment 2						
PB 86	16·49	20·75	27·23	35·95	43·27	46·6	30·11
RRIC 101	15·35	21·53	30·66	42·08	48·86	51·6	36·25
RRIC 102	17·22	23·63	31·73	42·14	49·59	52·8	35·58
	Experiment 3						
PB 86	17·76	22·36	31·20	37·98	42·70	47·6	29·84
RRIC 100	20·33	27·70*	33·89	43·86*	49·37	49·37*	35·07
RRIC 101	21·53	25·80	37·51	45·23*	50·74*	54·90	33·37

Mature *Hevea*

Eight field experiments varying in duration from 5 to 22 years have been in progress but only three experiments are discussed in detail.

Experiment 4

This experiment started in 1976, was designed to compare the effects of three levels of nitrogen, phosphorus, potassium and magnesium on growth and yield of mature rubber. The experimental trees were RRIC 45 planted in May/June 1967 at 6 X 3 m and grown with a mixed leguminous cover of *Pueraria phaseoloides* and *Desmodium ovalifolium* in an area receiving an average annual rainfall of 3125 — 3750 mm.

The soil, classified as Agalawatta series (Silva, 1964), is one on which rubber is commonly grown in Sri Lanka. Soils are of variable depth, often shallow, and frequently strewn with boulders and outcrops of the granatic rock, from which they are derived. They are silty clay loam in texture and strong brown to yellowish red in colour.

The three levels of nutrients tested were :

Nitrogen — 0, 105 and 210 g N as urea, phosphorus — 0, 115 and 230 g P_2O_5 as rock phosphate, potassium — 0, 115 and 230 g K_2O as potassium chloride (muriate of potash) and magnesium — 0, 35 and 70 g MgO as kieserites per tree per year. The fertilizer treatments were applied to experimental plots in a 3^4 factorial confounded design with single replication. In all experiments : (a) Each plot consisted of 30 to 40 measuring trees surrounded in all sides by one row of guard trees. (b) All fertilizers were forked into the soil at depths varying from 5 to 10 cm and tapping was done on the ½S d/2 system.

Experiment 5

This experiment was started in 1976, to test the effects of three levels of nitrogen and magnesium and two levels of phosphorus and potassium on growth and yield of rubber, on clone PB 86 planted in 1964. The ground cover conditions were similar to those in Experiment 1 and annual average rainfall varied from 2250 to 2500 mm.

Parambe series soil, another common rubber growing soil, was chosen for this experiment in view of its contrasting physico-chemical characteristics. These soils are deep, silty in texture and brown to reddish brown in colour, derived from micaceous parent material, the most common such parent material being a biotite gneiss.

The experimental design was a 3 X 2 X 2 X 3 factorial combination in single replication with levels, 0, 1 and 2 for N and Mg and O and 1 for P and K. The unit levels for the nutrients and other experimental details were approximately same as in Experiment 4.

Experiment 6

There are only a few reports of long term fertilizer experiments on *Hevea*, established and monitored from planting into the renewed panel stage. This experiment was designed to compare the effects of two levels of N, P and K on the performance of clone PB 86 since planting in 1961. Ground cover management practices and rainfall pattern were similar to those in Experiment 4.

The soil, a Boralu series, is shallow, gravelly loam, brown to reddish yellow in colour and overlying cabook. It is characterised by the presence of iron concretions which occur throughout the soil mass.

The nutrients N, P and K each at levels O and 1 were compared in a 2^3 factorial design, with four replicates. The unit levels of nutrients were approximately, 250 kg/ha of N as ammonium sulphate, 300 kg/ha of P_2O_5 rock phosphate and 300 kg/ha of K_2O as potassium chloride, during the immature period of 6 years. Thereafter, the rates were the same as in Experiment 4 and 5. All plants received uniform applications of Mg as kieserite.

Records and sampling

Yield recordings were made once a month from all central, measuring trees in each plot. This was done by measuring the total volume of latex and then coagulating 50 cc samples to obtain the dry rubber content in the usual manner. All the yield data were expressed as grammes dry rubber per tree per tapping per year.

Growth assessments were made by measuring trunk girths annually at a constant height of 150 cm above the union on all effective trees.

Sampling of leaves in the low shade position in July/August annually and soils whenever necessary, were done for chemical analyses by accepted procedures.

RESULTS

Pre-treatment yields were recorded for 6 months totalling 12 recordings in Experiments 4 and 5. Where post-treatment yields were affected by pre-treatment differences, as revealed in co-variance analysis, they were accordingly adjusted. A similar approach was adopted with trunk girth recordings. All post-treatment data were subjected to analysis of variance and where necessary partitioned into linear and quadratic components. Characterisation of soils by pre-treatment analysis (Table 6) indicated that in all experimental areas total N and P appeared to be satisfactory. K, Mg and cation exchange capacity (CEC) values were, however, comparatively much higher in Experiment 2.

Table 6. *Pre-treatment soil analysis*

Characteristics	Experiment — Soil — Sampling depth					
	Experiment 4 Agalawatta (granatic)		Experiment 5 Parambe (biotite gneiss)		Experiment 6 Boralu (cabook)	
	0 — 15 (cm)	15 — 30 (cm)	0 — 15 (cm)	15 — 30 (cm)	0 — 15 (cm)	15 — 30 (cm)
pH (water)	4·15	4·20	4·50	4·60	4·70	4·50
C (%)	1·86	0·97	1·40	0·54	2·12	0·76
N (%)	0·24	0·13	0·20	2·11	0·24	0·13
Total — P (ppm)	353	273	351	313	248	183
Available — P (ppm)	17·0	2·0	3·0	1·0	13·3	2·0
Total — K (me/100g)	3·33	3·21	5·76	6·07	2·43	3·46
Total — Mg (me/100g)	5·99	6·61	10·84	9·91	3·51	4·23
Exchangeable — K (me/100g)	0·12	0·04	0·27	0·21	0·07	0·02
Exchangeable — Mg (me/100g)	0·15	0·03	6·61	6·69	0·15	0·05
CEC (me/100g)	5·67	4·64	10·64	10·02	4·99	3·66

Total P by per chloric/sulphuric acid; available P by NH_4 F/HCl; total K and Mg by 6NHCl and exchangeable K and Mg and CEC by ammonium acetate at pH 7.

Nitrogen

Yield : The post-treatment mean yields for the different levels of nitrogen are given in Figs. 10, 11 and Table 7.

Table 7. *Effect of nitrogen and potassium fertilizers on yield (Experiment 5)*

Treatment	Yield (g/tree/tapping) 1977	1978	1979	1980	1981	1982	1983
N_0	25·77	34·50	32·32	20·88	25·83	29·60	32·20
N_1	25·72	33·60	34·67	24·82	24·31	35·00	34·20
N_2	24·41	34·10	34·64	24·46	24·88	33·80	32·70

In Experiment 4 there was a small increase in yield (Fig. 10) during the second year itself, due to application of nitrogen at level 1 and a further significant increase ($P < 0·05$) when nitrogen application was increased to level 2. These increases were more marked and significant ($P < 0·01$ and $P < 0·001$) thereafter. Partitioning into linear and quadratic components showed that the effects were significantly linear throughout the study period ($P < 0·05$ in 1977, 1978 and 1983) ($P < 0·01$ in 1979, 1980 and 1981) and ($P < 0·001$ in 1982).

As there had been no significant interaction of N with other nutrients, a closer scrutiny of the effects of N applied singly was made. Yield obtained with treatment combinations N_0 K_0, N_1 K_0 and N_2 K_0 were examined (Fig. 11), ignoring the effects of P and Mg; as they were considered less important. This revealed the highest yield response of 28% in 1979, 1980 and 1981 with nitrogen at level 2 in the absence of K.

Analyses of annual yield data of Experiment 5, did not detect any statistically significant effects of N, P, K or Mg on yield throughout the 8-year study period. However, a closer study (Table 7), as in Experiment 4, indicated small and inconsistent increases in yield to application of nitrogen.

In Experiment 6, only the last 8 years results, from 1976 to 1979 on the virgin panel and from 1980 to 1983 on renewed panel, are presented (Fig. 12). There had been consistently significant increases in yield (mostly at $P < 0·01$) to applications of nitrogen, but the magnitude of the response appears to have declined. In 1978 and thereafter, except in 1979, application of nitrogen tended to produce only slight increases (not significant) in yield.

Girth : Positive girth responses to applications of N were evident only in Experiment 4. Nitrogen treatments showed significantly higher girths (Fig. 13) at both N_1 and N_2 levels since 1978. Girth increment over the 8-year period had been very marked ($P < 0·001$) with increases of 12% and 24% for N_1 and N_2 levels, respectively. Partitioning of treatment effects showed significantly linear response ($P < 0·05$ in 1978 and 1979, P 0·01 in 1980 and $P < 0·001$ in 1981 and 1982) from the third year.

Leaf nutrient contents : Guided by the tentative critical range proposed by Yogaratnam and Silva (1977) pre-treatment leaf N contents were in general very low to low and leaf

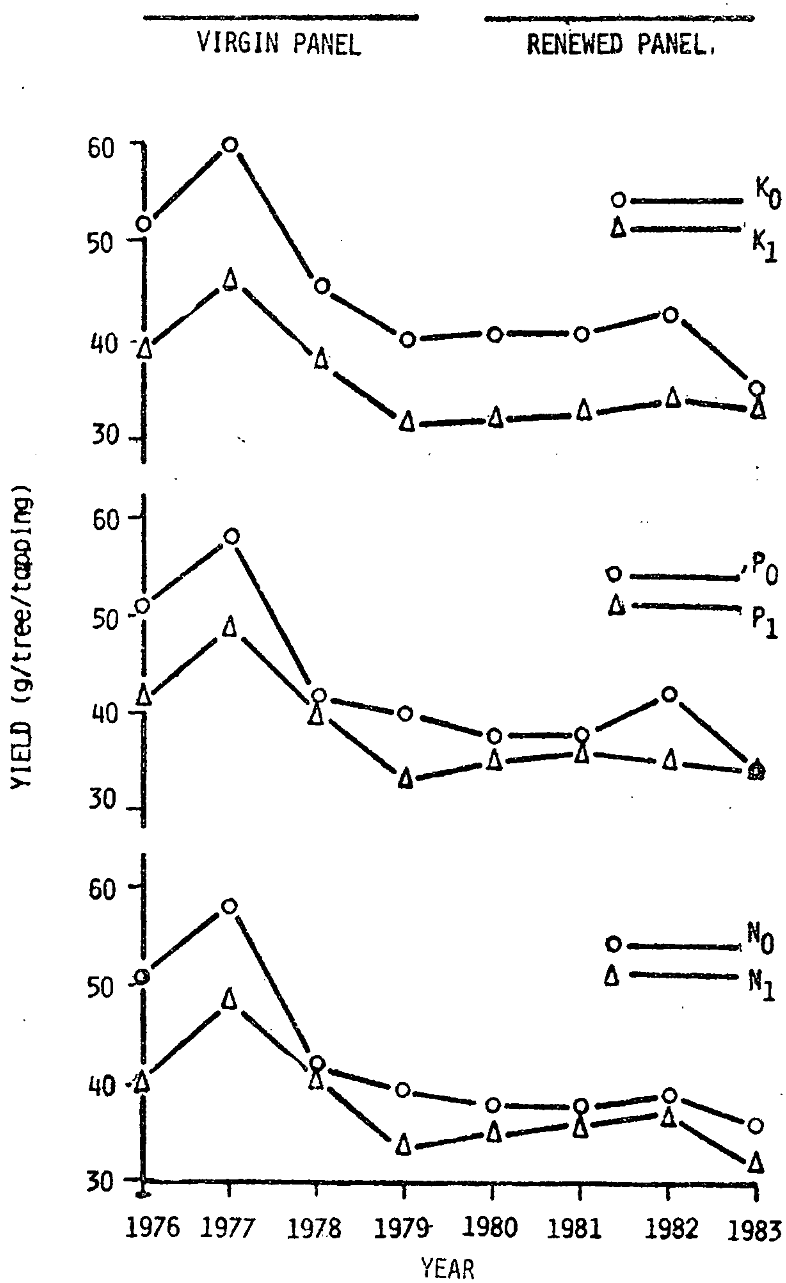


Fig. 12. Effect of nitrogen, phosphorus and potassium fertilizers on yearly mean yield — Experiment 3.

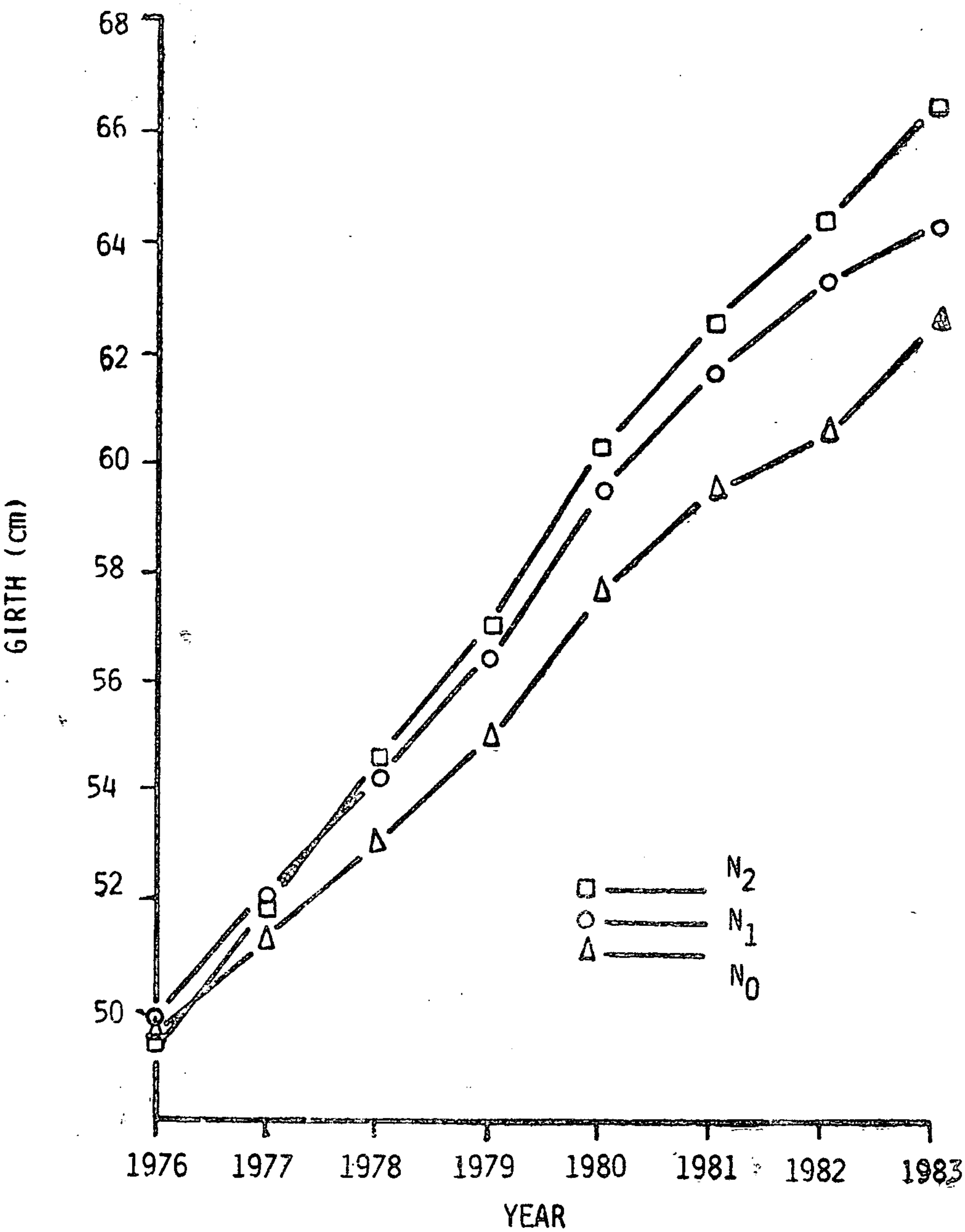


Fig. 13. Effect of nitrogen fertilizers on annual girth — Experiment 1.

P & Mg in the medium to high range and in some cases very high. Leaf K levels were, however, considered low in Experiment 4 and medium in Experiment 5.

Application of nitrogen at level 1 increased the leaf nitrogen content in Experiment 4 (Table 8) from 3·07 to 3·21% and a further increase ($P < 0.05$) to 3·32 at N_2 level in the second year itself. Thereafter, these differences were maintained fairly consistently, although the absolute values appeared to be below the suggested optimum range. Application of nitrogen was also found to decrease K content in leaves at N_1 level in 1977 ($P < 0.05$), 1978 ($P < 0.01$) and 1980 ($P < 0.05$) and N_2 level in 1977 ($P < 0.05$) 1978 ($P < 0.001$) and 1980 ($P < 0.01$).

Table 8. *Effect of nitrogen fertilizers on leaf nutrient content (Experiment 4)*

Treatment	Pre-treatment	1977	1978	1979	1980	1981	1982	1983
				Nitrogen (%)				
N_0	2·97	3·07	3·27	2·78	2·97	2·75	2·82	3·06
N_1	3·01	3·21	3·35	2·90	3·08	2·92	2·80	3·09
N_2	2·99	3·32*	3·47*	2·82	3·08	2·96*	2·95	3·23
N_0K_0	3·12	3·34	3·34	2·76	2·89	2·92	3·00	3·07
N_1K_0	2·94	3·27	3·27	2·84	3·12	2·97	2·77	3·23
N_2K_0	3·05	3·48	3·48	2·72	3·24	3·21	3·04	3·41
				Potassium (%)				
N_0	1·11	1·09	1·10	1·01	1·25	0·98	1·17	
N_1	1·04	1·02	1·03**	0·98	1·16	0·93	1·22	
N_2	1·08	1·03	1·01***	0·99	1·14	0·95	1·21	

In this and all other tables, *, **, and *** indicate those treatments differing from the control (zero level) at P = 0·05, 0·01 and 0·001, respectively.

In Experiment 5, application of nitrogen showed a tendency to increase leaf N (Table 9). But in Experiment 3, leaf N content (Table 10) had been consistently higher in plots that received N regularly although the absolute values in the control and treated plots were much below the sufficiency levels.

Table 9. *Effect of nitrogen and potassium fertilizers on leaf nutrient content (Experiment 5)*

Treatment	Pre-treatment	1978	1980	1981	1982
			Nitrogen (%)		
N_0	2·76	2·67	2·76	2·94	2·39
N_1	2·61	2·82	2·87	2·84	2·53
N_2	2·74	2·83	2·82	2·92	2·53
			Potassium (%)		
K_0	1·58	1·56	1·61	2·74	2·68
K_1	1·53	1·57	1·70	2·59	2·63

Table 10. *Effect of nitrogen, phosphorus and potassium fertilizers on leaf nutrient content (Experiment 6)*

Treatment	1976	1977	1978	1979	1980	1981	1982
				Nitrogen (%)			
N_0	2·65	2·71	2·42	2·39	3·15	2·56	2·34
N_1	2·85*	2·94	2·71**	2·51	3·33	2·75	2·54*
				Phosphorus (%)			
P_0	0·19	0·17	0·18	0·20	0·18	0·21	0·17
P_1	0·21*	0·20*	0·22**	0·24**	0·20	0·23	0·20
				Potassium (%)			
K_0	0·96	0·76	0·88	0·66	0·84	0·68	0·67
K_1	1·28**	1·04*	0·01	0·97**	1·02	0·96**	0·97*
				Magnesium (%)			
K_0	0·25	0·31	0·29	0·35	0·33	0·30	0·29
K_1	0·25	0·25**	0·28	0·29**	0·28*	0·24*	0·25

Potassium

Yield : Application of K in Experiment 4 gave small yield increases (Fig. 14) when applied singly at the first level. The lag period between commencement of experimental fertilizer treatment and response was about 4 years. The magnitude of the response over the control was only 7 and 8% in 1981 and 1982 respectively. However in 1983 significant interaction ($P < 0·05$) between K and P on yield was evident. Partitioning of PK interaction effect revealed a linear response to K ($P < 0·01$) with the slope of this response varying with the level of P in a linear manner (Fig. 15).

Significant yield increases were observed with application of K in Experiment 6 (Fig. 12) but not in Experiment 5. The magnitude of this response was higher in the virgin panel, ranging from 17 to 33% in comparison with 13 to 28% in the renewed panel.

Girth : Significant interaction between K and Mg on girth increase over the 7-year period from 1976, was observed in Experiment 4, this effect was significantly quadratic (Fig. 16). It therefore follows that the quadratic response in girthing with application of Mg varied the levels of K.

Leaf nutrient contents : According to deficiency/sufficiency criteria, all experimental trees in experiment 4 and 6 exhibited very low K content at the onset but the values in Experiment 5 appeared to be very high.

Potassium content of leaves (Table 11) were significantly increased ($P < 0·05$) by application of K at both K_1 and K_2 levels in Experiment 4, within 1 year. The responses became more marked in subsequent years, attaining statistical significance at 0·1% level except in 1981 (at 5% level). Inspite of these marked increases, leaf K levels never reached the sufficiency levels suggested for optimum performance of the tree.

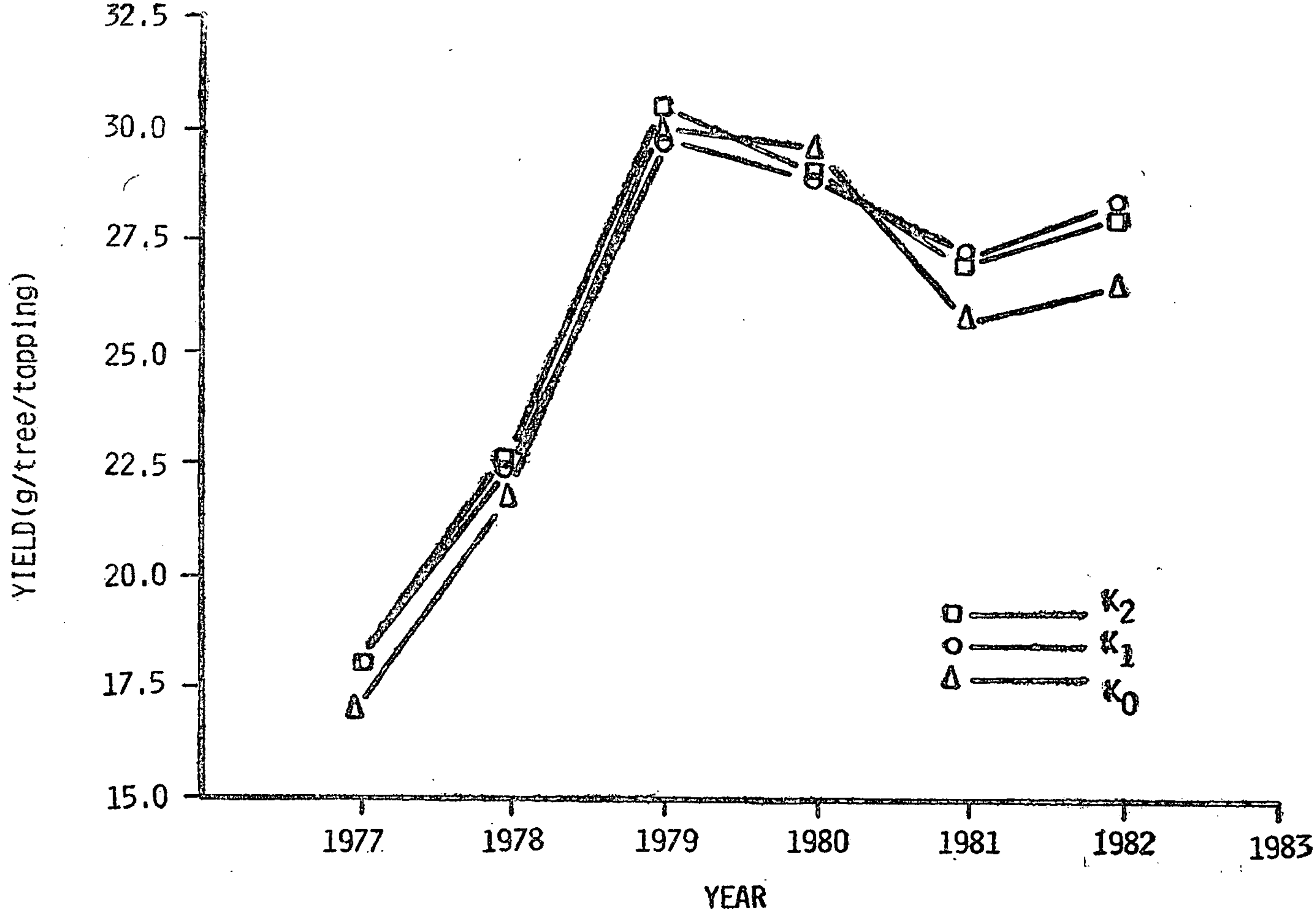


Fig. 14. Effect of potassium fertilizers on yearly mean yield — Experiment 1.

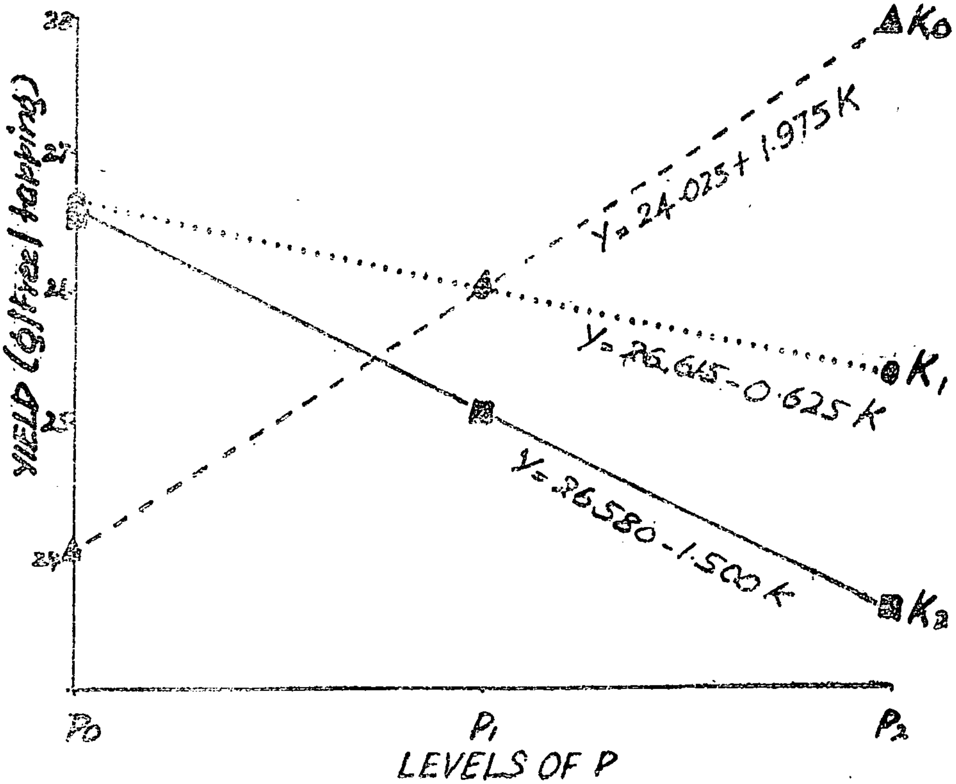


Fig. 15. Effect of potassium and phosphorus fertilizers on mean yield in 1983 — Experiment 4.

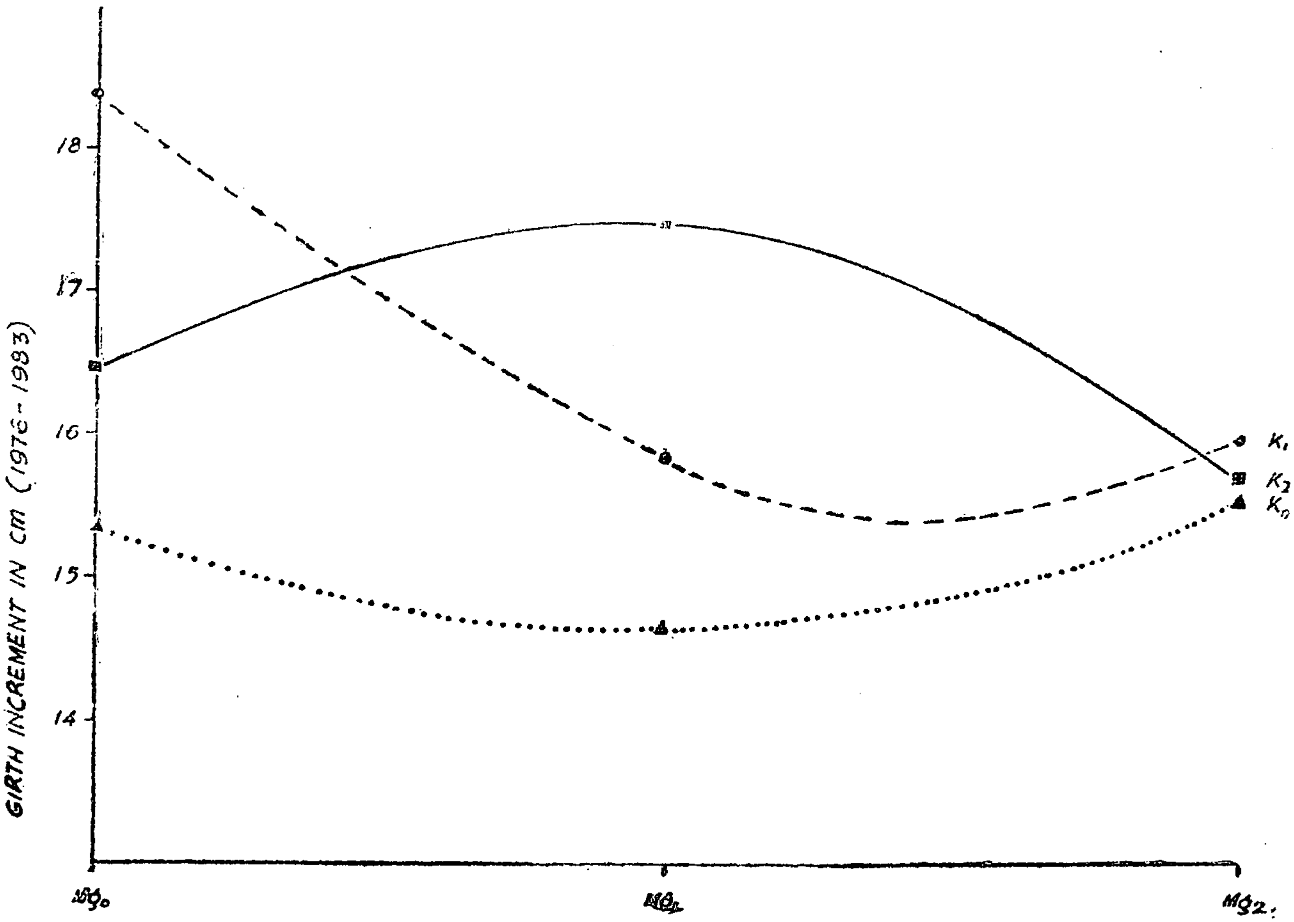


Fig. 16. Effect of potassium and magnesium fertilizers on girth increment from 1976 to 1983 — Experiment 1.

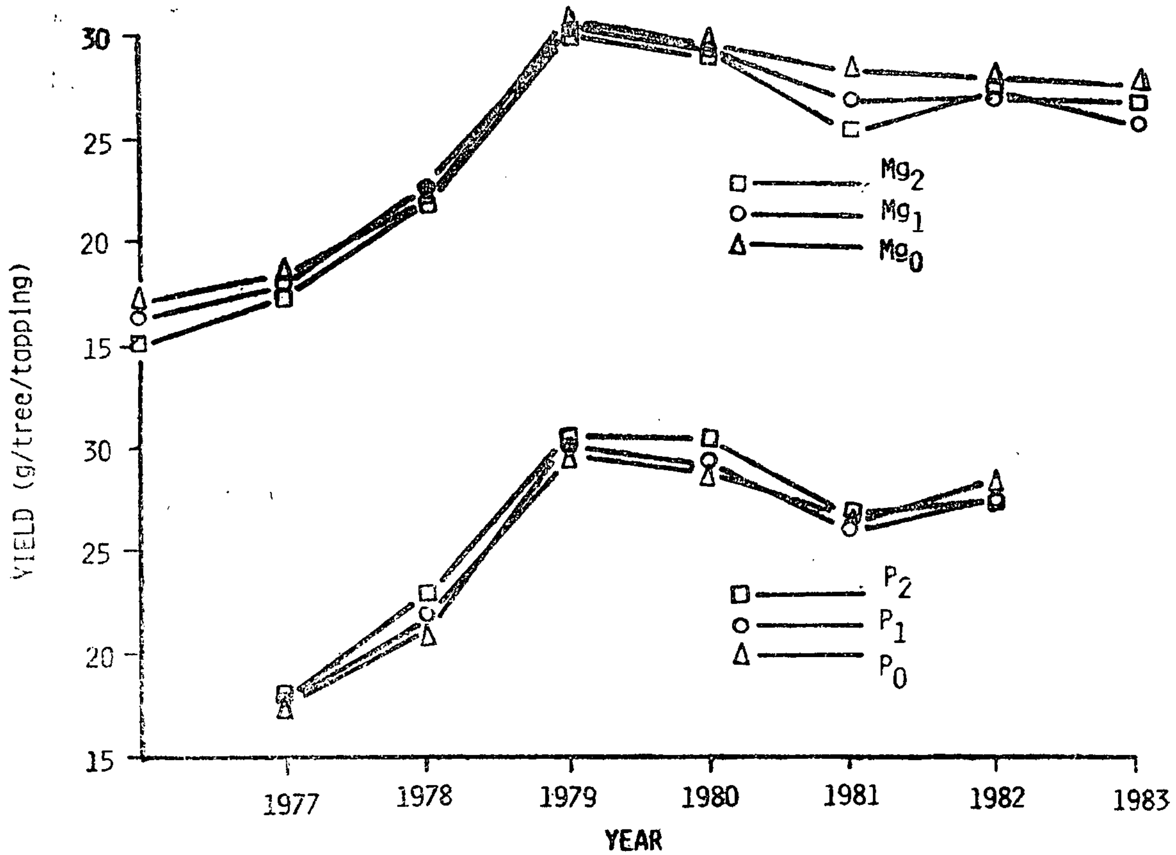


Fig. 17. Effect of magnesium and potassium fertilizers on yield.

Table 11. *Effect of potassium fertilizer on leaf K content (Experiment 4)*

Treatment	Potassium (%)					
	Pre-treatment	1977	1978	1980	1981	1982
K_0	1·04	0·97	0·96	0·99	0·78	1·00
K_1	0·99	1·04*	1·06***	1·26***	0·93*	1·14**
K_2	1·01	1·07	1·10***	1·31***	0·95*	1·21***

Leaf P contents were significantly decreased with application of K in 1980 ($P < 0{\cdot}01$) and 1981 ($P < 0{\cdot}05$) and there were similar tendencies in other years. Application of potassium at K_2 level tended to decrease the Mg content in leaves which was significant ($P < 0{\cdot}05$) in 1980 and 1982 (results not presented). In Experiment 2, potassium fertilizers had no effect on the K content in the leaves (Table 9).

Phosphorus

Yield : Application of phosphorus significantly increased yield ($P < 0{\cdot}01$) only in Experiment 6 (Figs. 12 and 17). Yield increases ranging from 19 to 22% were obtained from the virgin panel except in 1978. Response from renewed panels has been mostly below 10% except in 1982 when a 20% increase was obtained.

Leaf nutrient content : Phosphate application tended to increase leaf P content in Experiment 4 (Table 12), these increases were significant ($P < 0{\cdot}05$) in 1978, 1980 and 1983). Similar increases were observed in Experiment 6 (Table 10).

Table 12. *Effect of phosphorus fertilizers on leaf P content (Experiment 4)*

Treatment	Phosphorus (%)					
	Pre-treatment	1977	1978	1980	1981	1982
P_0	0·20	0·19	0·19	0·24	0·19	0·24
P_1	0·21	0·19	0·20	0·25	0·22	0·25
P_2	0·20	0·21	0·21*	0·26*	0·20	0·25

Magnesium

Yield : Magnesium fertilizers at level 2 tended to show depressive effects on yield in Experiment 4 (Fig. 17) attaining statistical significance ($P < 0{\cdot}05$) in 1976, 1981 and 1983.

Leaf nutrient content : Leaf Mg contents were significantly increased with application of Mg at both Mg_1 and Mg_2 levels (Table 13). These increases have been obtained inspite of the very high leaf Mg levels of over 0·25% at the onset.

Sulphur : In view of the present practise of using urea as the source of nitrogen in rubber plantations, the SO_4 contents of the leaf and soil were also monitored. The SO_4 contents in leaves were decreased from 2600 to 2520 mg/kg with the application of urea at N_1 level and a further significant decrease ($P < 0 \cdot 01$) to 2422 mg/kg was obtained at N_2 level. A similar decrease in soil SO_4 content from 340 to 308 mg/kg was also observed when the nitrogen level was increased from N_0 to N_2.

Table 13. *Effect of magnesium fertilizers in leaf Mg content (Experiment 4)*

Treatment	Magnesiun (%)						
	Pre-treatment	1977	1978	1979	1980	1981	1982
Mg_0	0·30	0·29	0·33	0·28	0·32	0·27	0·25
Mg_1	0·31	0·32*	0·32	0·30	0·34*	0·30**	0·29***
Mg_2	0·29	0·33*	0·34	0·31*	0·36***	0·31**	0·30***

DISCUSSION

Yogaratnam and Silva (1984) showed that fertilization with N, P and K led to significant increases in the corresponding leaf N, P and K concentrations. Data on girth, girth increment and percentage tappability have shown that consistent increases in growth and consequently shortening of unproductive period have resulted from fertilizer application.

An increase in the concentration of a particular mineral constituent will not necessarily influence growth, unless the change is effected within the range of critical concentrations associated with the development of its deficiency. In cases where the concentration for control plots was low, compared to what is generally considered satisfactory (Pushparajah *et al*, 1983) the fertilizer effect, as would be expected, was more marked. It therefore appears that values for total nitrogen varying from 0·185 to 0·205% in the soil are unlikely to be sufficient, unlike the phosphate levels. Phosphate fertilization, in spite of the satisfactory levels of 202 to 337 ppm of 'total' and 'available' P respectively in the soil, may result in the build up of phosphate in the soil (Pushparajah, 1977) and such accumulation of phosphate during the immature period is likely to be sufficient to sustain the rubber trees at least during the early productive period (Yogaratnam *et al*, 1976) in addition to the reduction in the immature period. In as far as K was concerned, although total K (6N HCl extractable) was in the satisfactory range of 2·95 to 3·27 me/100g, unexpected (Pushparajah, 1977) early and marked responses to K fertilization may have been influenced by the low 'exchangeable K' levels of 0·045 to 0·081 me/100g in soil.

Although a detailed statistical analysis was not done on percentage tappability data, the close pattern of responses between girthing and percentage tappability suggests that the fertilizer effects which influenced girthing were equally effective on tappability. It seems that the trees were fairly uniform and it is likely that on tapping the yields could be fairly high and consistent, as high tree variability in field buddings was known to delay the attainment of tappability and hence early yields (Sivanadyan *et al*, 1975).

In general, the RRIC 100 series clones have performed much better than PB 86 with the final girths of PB 86, receiving the highest level of NPK fertilization, being comparable only to the RRIC 100 series clones without any added fertilizers. This however may not be acceptable ; as yields from similar girths for fertilized trees, increases latex vessel number and their size and also starch reserves in the bark (Samsidar *et al*, 1975 and Haridas *et al*, 1975). Moreover, unlike unfertilized trees, opening for tapping is not likely to lead to significant effects on retarding girth increment in fertilized trees (Sivanadyan *et al*, 1975).

As the required tappable standard in response to N fertilization, had not been attained by PB 86 even at the end of 7 years, comparisons made at the point of maximum percentage tappability by PB 86, revealed that with nitrogen application at the rate of 310 kg/ha it was possible to shorten the unproductive period in RRIC 100, 101 and 102 by 3, 6 and 9 months respectively in areas under pure legume covers and by 9 and 12 months in RRIC 101 and 102, respectively, in areas under mixed growth of naturals and legumes. Increasing the level to 620 kg N/ha resulted in a further appreciable reduction of over 12 months in the non-legume areas only. The vital importance of pure legume covers in promoting the maturity of immature *Hevea*, has been highlighted by other workers also (Mainstone, 1961 and Pushparajah and Chellapah, 1969). Phosphorus application at the rate of 160 kg P/ha could also reduce the immature period by about 12 and 18 months in RRIC 101 and 102, respectively, compared to PB 86, with no further benefit at higher levels of applied P. Similarly, with K fertilization at the rate of 310 kg K/ha it had been possible for the trees to be opened for tapping in periods varying from 68 to 74 months and 62 to 64 months and in about 66 months by RRIC 100, 101 and 102, respectively, which means reductions in the range of 14 to 18 months and 24 to 26 months for RRIC 100 and 101, respectively, and about 25 months for RRIC 102. Therefore, in the absence of any significant interaction effects between nutrients, it would be possible to shorten the unproductive period from over 84 months (7 years) to about 60 months (5 years) with NPK fertilization at rates varying from 190 to 310 kg N, 100 to 160 kg P and 190 to 310 kg K, per hectare during the 5-year immature period.

Several innovations developed in order to reduce the immature period such as, brown buddings (Sivanadyan *et al*, 1975), green buddings (Hurov, 1961) developments in green budding (Tinley, 1962), budded materials in polybags (Tinley, 1962), induction of branching (Yoon, 1972) stumped buddings (Strivens, 1962), white washing the stem with lime (Yogaratnam *et al*, 1976), stumped buddings with agronomic manipulations and polybag-raised plants (Yoon *et al*, 1976) and fertilizer application at greater frequencies (Sivanadyan *et al*, 1973) have not been used extensively due to various setbacks. However, the conventional system of planting with budded stumps of good vigour, transplanted as bare rooted stumps and manipulated by fertilizers, is likely to be more acceptable, particularly to smallholders covering about 75% of the total area of approximately 7 million hectares of planted *Hevea* in the world (Barlow, 1983), in view of their low cost, labour requirements and technology inputs, for establishment. Some important constraints in this system would be, dry-tree incidence (brown bast) as reported for clone RRIC 101 (Samaranayake, 1984) and wind damage (Jeevaratnam, 1964). If vigour of the tree influences high latex flow, which precedes the incidence of dry-trees (Samaranayake, 1984), then minimizing dry-tree occurrence in clone RRIC 101 by retarding the vigour of the tree with reduced fertilization, is a possibility as the clone RRIC 101 had been found to be very sensitive to application of fertilizers, particularly K (Fig. 6). Applications at the reduced levels in the region 125 to 155 kg N, 65 to 80 kg P and 125 to 155 K per ha may retard the vigour of the tree, resulting in the extension of the immature period (Figs. 2, 3, 5, 7 and 8) by about 3 to 4 months with N and P about 3 to 6 months with K fertilizers. While retarding the vigour, nutritional condition of the tree had also been considered for reasons suggested earlier (Samsidar *et al*, 1975 and Haridas *et al*, 1975). This however, has to be substantiated with more data and these experiments are being continued.

This study has shown that fertilization with acceptable levels in the range of 190 to 310 kg N as urea 100 to 160 P as rock phosphate and 190 to 310 kg K as muriate of potash, is an efficient, practical method of increasing the vigour of immature *Hevea* cultivars. Increasing the levels of nutrients beyond the suggested levels would not give any additional benefit except with nitrogen under a mixed growth of naturals and legume ground covers. In such instances, increased levels of nitrogen as urea even at rates as high as 380 to 620 kg/ha would improve girthing. The response to NPK fertilization in terms of tappability of trees closely followed the girthing pattern and in general, the clones of the RRIC 100 series have been more vigorous in growth than PB 86 and this effect was similar at all levels of N, P and K. Therefore, in the absence of any other convincing horticultural or agronomic practices, introduction of vigorously growing cultivars under the conventional systems of planting and fertilizing them with the acceptable levels of fertilizers would be a major contribution to shortening the unproductive period in the planting cycle of *Hevea*. A saving of 18 to over 24 months by this method must be regarded as a substantial gain.

Application of nitrogen to mature rubber under Sri Lankan conditions has been proved to be beneficial even in areas with good agronomic management history. Yield responses to nitrogen in Experiment 4 closely followed the response of girth but have been more marked suggesting a quadratic relationship (Paardekooper, 1970) of yield on girth. It is possible that either larger trees, as a consequence of increased nitrogen application, may have thicker bark, although this had not been proved in another study (Yogaratnam, 1980 and 1981) and greater length of the tapping cut or larger trees yield more per inch of the tapping cut than the smaller trees.

The general belief that nitrogen application may not be required during the early mature period (Pushparajah and Chellapah, 1969, Guha, 1975 and Sivanadiyan, 1983) may not be acceptable under local conditions, where the beneficial effects of legume covers do not persist as long under Sri Lankan agro-climatic conditions, especially in view of our higher rainfall conditions. Yogaratnam and Perera (1981) reported a declining response to application of nitrogen from 4 years after planting. It therefore appears that the beneficial effects of legumes may not have gone beyond 1975 *i.e.* 8 years from planting in Experiment 1. This has been suggested by the low pre-treatment leaf nitrogen content (Table 8). Indeed even with the N_2 level of nitrogen which is double the currently recommended rate, it was not possible to raise the nitrogen content to the optimum levels, consistently. The importance of nitrogen on the performance of tree crops has been emphasised by several workers, Yogaratnam and Perera (1981) and Peries and Yogaratnam (1982) in *Hevea*, Bavanandan and Sundaralingam (1969) and Peries and Yogaratnam (1982) in tea, Loganathan (1978) and Peries and Yogaratnam (1982) in coconut, Ng (1979) in oil palm and Yogaratnam and Greenham (1982) in apple.

The absence of other nutrients in particular K on N responses, in contradiction with the reports of other workers (Guha, 1975), suggests that these nutrients were present at low levels but adequate for optimum performance of the trees. On the contrary, application of K singly had also been found to increase yields, of course with a time lag of 4 years from the time of application. It may be that trees adapted to poor environment of inherently low exchangeable K (0·04 me/100g), would exhibit optimum performance even under low leaf K contents (Table 6). Moreover, these trees are believed to be less sensitive to environmental changes hence the delayed development of yield responses to K fertilizers. Further, although it appears difficult to explain the quadratic pattern of the K-Mg interaction (Fig. 16) yet, it is evident that the beneficial effect of K on girth increase over the 8 year period had been eliminated by high levels of Mg fertilizers. A similar antagonism existed between K and P at the highest levels, on yield in 1983 (Fig. 17). It now appears that the leaf K deficiency/sufficiency levels for diagnostic purposes may have to be revised for the low — K areas. A leaf potassium content of 1·05% would perhaps be adequate, while a value of 0·85% or below would perhaps be deficient. It would be beneficial if P and Mg fertilizers are also kept within reasonable limits.

Discontinuation of N application at a later stage of the cycle, probably in the second virgin panel or even later may be considered, based on the results from Experiment 5 on Parambe soils. Adequate fertilization with other sound agronomic practices, during the early immature period, as evident from field records, would have provided a continuous but steady supply of a large amount of nutrients, in particular N, from legume covers that mineralise rapidly with its nutrient content becoming quickly available again for uptake by *Hevea* (Yogaratnam *et al*, 1976). This followed by more nitrogenous fertilizers during the early mature phase would have enabled a steady build up of nutrient reserves within the whole tree system (Tan, 1975). This may possibly sustain the nitrogen needs of mature trees during the later stages.

The importance of N, P and K application during the immature period has also been amply emphasised in Experiment 6 on boralu soils, as reported earlier by Jeevaratnam (1969). Diminished responses to applications of NPK fertilizers during the later stages of the cycle (renewed panel) may have been due to the absence of well balanced nutrition. This could not be avoided in this experiment as the treatments were arranged in a factorial combination where the inclusion of a control (zero level) for each nutrient would have caused severe nutritional stress on some experimental trees thus restricting normal physiological activities in the tree. This would have been further enhanced by regular uniform applications of Mg fertilizers, as reflected by the very high leaf Mg contents (Table 10). High levels of Mg application were also found to depress yields in Experiment 4, supporting earlier reports (Law and Tan, 1977).

Although leaf and soil SO_4 contents were reduced by the continuous use of urea at both N_1 and N_2 levels in Experiment 4, yet the absolute values were much above the normal range of SO_4 content for agricultural soils in other countries (Muller and Sissingh, 1980). The use of sulphur for disease control in rubber plantations may have also contributed to the high levels of SO_4 in rubber soils.

Mature rubber plantations with agro-forestry systems of cultivation are likely to conserve and utilize the reserve of nutrients more effectively than other agricultural systems. Nutrient re-cycling is very efficient with relatively small loss of nutrients through the latex (Sivanadiyan *et al*, 1972). Further, the fertilizer requirements of trees under tapping are also expected to diminish in view of the reduction in tree biomass, resulting from intensified self-pruning and thinning of canopy.

Experiments done under Sri Lankan agro-climatic conditions, demonstrates that judicious fertilizer application is required for proper economic benefit to be derived. However, unlike in other countries, N application should be continued uninterrupted during the initial period of tapping at least in the virgin panels. Thereafter, soil and leaf analysis could be used as a guide. On the other hand, discontinuation of K fertilizers may be considered in areas with K content (6 N HCl extractable K), ranging from 5 to 6 me. per 100 g soils, such as the soils derived from biotite gneiss (micaceous parent material). Similarly, P and Mg applications may also be discontinued for several years, particularly Mg application, in areas with Mg levels ranging from 5 to 6 me. such as the granite derived and the cabook type soils.

It should however, be appreciated that the recommendations suggested in this paper would apply only to replanted areas which received high standards of agronomic management, including adequate manuring and legume covers, during the immature phase.

Profitability of fertilizer use

To consider the approximate profitability of fertilizer use (Table 14) yields over the 7-year period have been considered and the mean and standard deviation (Figs. 18 and 19) have also been worked out.

Table 14. *Value/cost ratio*

	Yield category		
	Lower	Mean	Upper
N_1K_0	2·5	3·1	3·7
N_2K_0	2·6	3·2	3·8
N_1K_1	1·3	1·3	1·4
N_2K_1	1·7	2·2	2·7

Value of rubber @ Rs. 15/- per kg
fertilizer — unsubsidised rates, labour wages at current rates, cost of handling, storage, transport etc. not considered.

The concept of value/cost ratio is used here to assess the profitability of fertilizer use. This concept was introduced by the FAO for similar fertilizer programmes. This refers to the ratio of the value of increased production following fertilizer use to the cost of this fertilizer. A V/C ratio of 2 or more is generally considered to suggest that it would

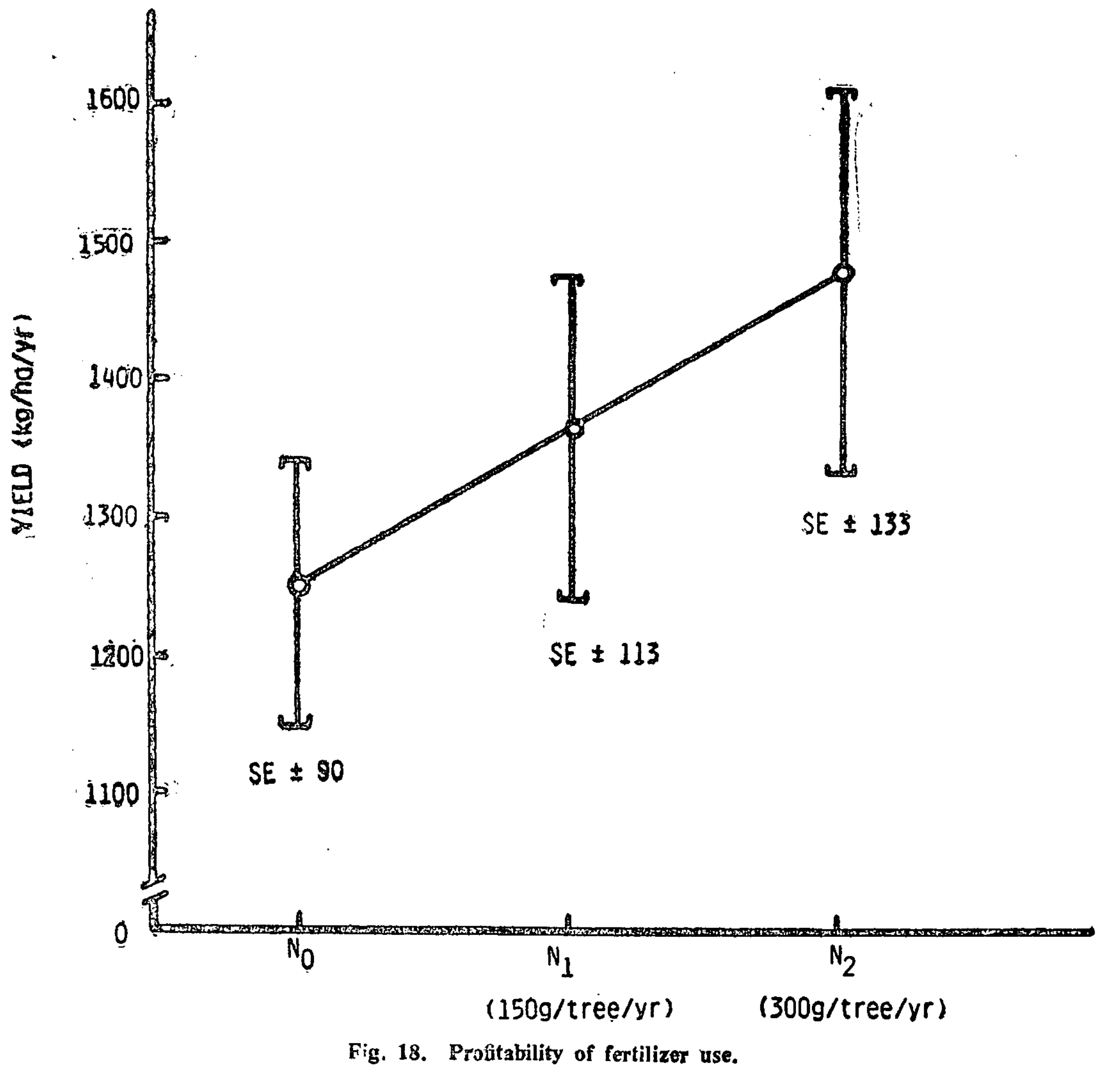


Fig. 18. Profitability of fertilizer use.

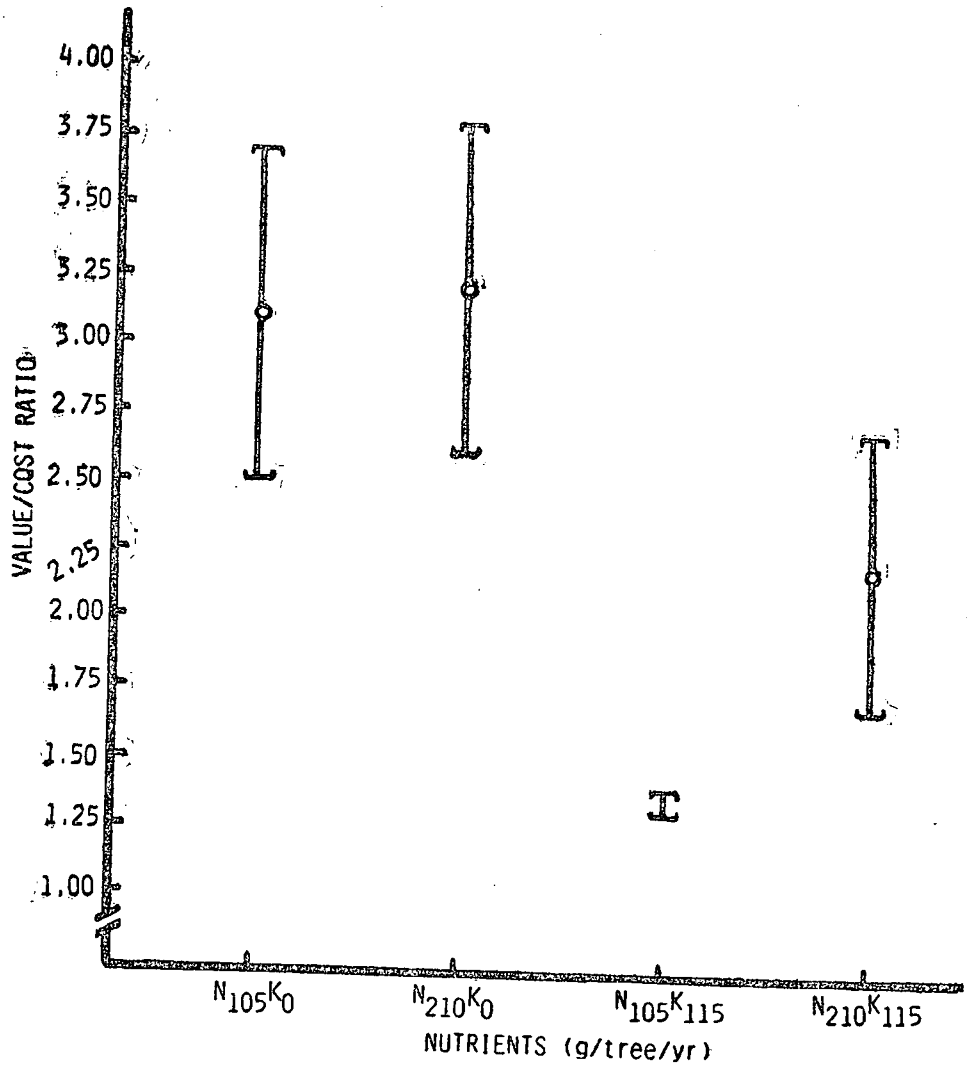


Fig. 19. Approximate value/cost ratios for different yield categories.

be profitable to use fertilizers. Based on the yield category shown in the previous slide for nitrogen at level 1 in the absence of K, the V/C ratio is 3·1 with the lower limit of 2·5 and upper limit of 3·7. When nitrogen was increased to level 2, there had been no change in the V/C ratios although in terms of yield, N_2 level gave the highest yield. This obviously indicates that nitrogen application at level 1 would be sufficient for maximum economic yield, in the absence of K. But when K fertilizer is also applied, N may have to be increased to level 2, in order to get an acceptable V/C ratio.

CONCLUSION

The basic philosophy of the current approach to fertilizer recommendations is the integration of soil survey and soil and leaf nutrient data with results of fertilizer experiments to increase reproducibility of these results for wider application in the field. Thus, no single factor can stand on its own ; an integrated picture of all these factors is essential to provide an accurate fertilizer recommendation to a particular area.

ACKNOWLEDGEMENT

The authors wish to thank the technical and field staff of the Soils and Plant Nutrition Department for technical assistance and the Biometry Section for some statistical analysis.

REFERENCES

BARLOW, C. (1983). The natural rubber industry. *The Planter* **59**, No. 687, 252 - 267.

BARLOW, C. AND NG, C. S. (1966). Budgetting on the merits of a shorter immature period. *Plr's. Bull. Rubb. Res. Inst. Malaya* No. 87, 216 - 236.

BHAVANANDAN, V. P. AND SUNDARALINGAM, S. (1971). The effect of nitrogen fertilizers on soil acidity, soil urease activity and leaf nutrient content on yield of tea. *The Tea Quart.* **42**, 40 - 47.

BOLTON, J. (1960). The response of *Hevea* to fertilizers on a sandy latesol. *J. Rubb. Res. Inst. Malaysia* **16** (4) 178.

FERNANDO, D. M. (1977). Some aspects of *Hevea* breeding and selection *J. Rubb. Res. Inst. Sri Lanka* **54**, 17 - 32.

GUHA, M. M. (1975). Fertilizer response from mature rubber in Liberia. *Proc. Inst. Rubb. Conf. Kuala Lumpur*, 1975, 108 - 121.

HARIDAS, G., SIVANADYAN, K., TAN, K. T., P'NG, T. C. AND PUSHPARAJAH, E. (1975). Inter-relationship between nutrition and exploitation of *Hevea brasiliensis*. *Inst. Rubb. Conf.* Kuala Lumpur 1975.

HUROV, H. R. (1961). Green-bud strip budding of 2 to 8 month old rubber seedlings. *Proc. Nat. Rubb. Res. Conf. Kuala Lumpur*, 1960, 419 - 428.

JEEVARATNAM, A. J. (1964). Tree damage caused by wind in rubber plantations. *Quart. J. Rubb. Res. Inst. Ceylon* **40,** 64 - 73.

JEEVARATNAM, A. J. (1969). Relative importance of fertilizer application during pre and post-tapping phases of *Hevea. J. Rubb. Res. Inst. Malaysia* **21** (2), 175.

LAW, W. M. AND TAN, M. H. (1977). Chemical properties of some peninsular Malaysian soil series. *Proc. Conf. Fert. Chemy. Trop. Soils, Kuala Lumpur* 1973, 180.

LIM, S. C., HO, C. Y. AND YOON, P. K. (1973). Economics of maximising early yields and shorter immaturity. *Proc. Rubb. Res. Inst. Malaya Plr's. Conf. Kuala Lumpur* 1973, 1 - 15.

LOGANATHAN, P. (1978). Yield and growth responses of young coconut to NPK fertilizers on a sandy soil in Sri Lanka. *Proc. of the 34th Annual Sessions, SLAAS, Sri Lanka 1978.*

LORD, L. (1929). The effect of nitrogen on the yield of rubber. *Trop. Agric. Mag., Ceylon Agric. Soc.* **72,** 127.

MAINSTONE, B. J. (1961). Effects of ground cover and continuity of nitrogenous fertilizer treatment on growth to tappable maturity of *Hevea brasiliensis. Proc. Nat. Rubb. Res. Conf. Kuala Lumpur,* 1960, 362 - 375.

MAINSTONE, B. J. (1962). Dunlop polythene bag planting technique. *Plrs'. Bull. Rubb. Res. Inst. Malaya* No. 63, 154 - 161.

MULLER, A. AND SISSINGH, H. A. (198). First progress report on the " Cooperative study of possibilities of standardization and improvement of soil testing methods of soils form the humid tropics with emphasis on soil phosphate (CSST) 1978 -- first half 1979. Royal Tropical Institute, Amsterdam.

NG, S. K. (1976). Review of oil palm manuring. Scope for greater economy in fertilizer usage. *Malaysia International Agricultural Oil palm Conf. Kuala Lumpur,* **1976,** 209 - 233.

PAARDEKOOPER, E. R. (1970). Relative importance of fertilizer application during pre and post-tapping phases of *Hevea. J. Rubb. Res. Inst. Malaysia* **21,** 127, 175, (discussion of paper).

PERIES, O. S. AND YOGARATNAM, N. (1983). Fertilizer use among perennial crops. *Proc. of the 8th consultative group on the FAO fertilizer programme, Colombo.*

PUSHPARAJAH, E. (1977). Nutritional status and fertilizer requirements of Malaysian soils for *Hevea brasiliensis.* Thesis submitted to University of Ghent for degree of Doctor of Science.

PUSHPARAJAH, E. AND CHELLAPAH, K. (1969). Manuring of rubber in relation to covers. *J. Rubb. Res. Inst. Malaya* **21**, 126 - 139.

PUSHPARAJAH, E., SIVANADYAN, K. AND YEW FOONG KHEONG (1974). Efficient use of fertilizers. *Proc. Rubb. Res. Inst. Malaya Plrs'. Conf. Kuala Lumpur* 1974, 102.

PUSHPARAJAH, E., CHAB HEUN YIN AND SIVANADYAN, K. (1983). Recent development for reduced fertilizer application for *Hevea*. *Rubb. Res. Inst. Malaysia Plrs'. Conf. Kuala Lumpur* 1983, Preprint 18, 18.

SAMARANAYAKE, C. (1984). Personal communication.

SAMSIDAR HAMZAH ABDUL AZIZ MAHOOD, SIVANADYAN, K. AND GOMEZ, J. B. (1975). Effects of mineral deficiencies on bark anatomy of *Hevea brasiliensis*. *Int. Rubb. Conf.* Kuala Lumpur 1975.

SILVA, C. G. (1964). Provisional classification of rubber soils of Ceylon and their relationship to Malayan soils. *J. Rubb. Res. Inst. Malaya* **24**, 145.

SIVANADYAN, K. (1972). Lysimeter studies on the efficiency of some potassium and nitrogenous fertilizers on two common soils in West Malaysia. *Proc. 2nd Asian Soil Conference Djakarta, 1972.*

SIVANADYAN, K. (1983). Manuring of mature *Hevea* : Recent evidences and a possible new outlook. *Preprint Planters' Conference 1983.*

SIVANADYAN, K. MUSA BIN MOHD SAID, WOOD YIN KHEE, SOONG NGIN KWI AND PUSHPARAJAH, E. (1973). Agronomic practices towards reducing period of immaturity. *Proc. Rubb. Res. Inst. Plrs'. Conf. Kuala Lumpur* 1973, 226 - 242.

SIVANADYAN, K., HARIDAS, G. AND PUSHPARAJAH, E. (1975). Reduced immaturity period of *Hevea brasiliensis*. *Int. Rubb. Conf.* 1975 *Kuala Lumpur* 147 - 157.

STRIVENS, L. V. (1962). Planting stumped buddings. *Plrs'. Bull. Rubb. Res. Inst. Malaya* No. 62, 148 - 151.

TAN, K. T. (1975). Seasonal changes in the concentration of nutrients in mature *Hevea*. *Proc. Int. Rubb. Conf. Kuala Lumpur* 1975, 73 - 83.

TI TEOW CHAN, PEE TECK YEW AND PUSHPARAJAH, E. (1971). Economic analysis of cover policies and fertilizer use in rubber cultivation. *Proc. Rubb. Res. Inst. Malaya Plrs'. Conf. Kuala Lumpur* 1971, 214 - 219.

TINLEY, G. A. (1962). Propagation of *Hevea* by budding young seedlings. *Plrs'. Bull. Rubb. Res. Inst. Malaya* No. 62, 136 - 147.

YOGARATNAM, N. (1980). Review of the Soils and Plant Nutrition Department for 1979. Rubber Research Institute of Sri Lanka, 81.

YOGARATNAM, N. (1981). Review of the Soils and Plant Nutrition Department for 1980. Rubber Research Institute of Sri Lanka, 73.

YOGARATNAM, N. AND GREENHAM, D. W. P. (1982). The application of foliar sprays containing nitrogen, magnesium zinc and boron to apple trees. I. Effects on fruit set and cropping. *J. Hort. Sci.* **57** (2), 1982.

YOGARATNAM, N. AND PERERA, M. A. (1981). Urea as a nitrogen fertilizer for rubber plantations in Sri Lanka. II. Agronomic investigations. *J. Rubb. Res. Inst. Sri Lanka* **59**, 20 - 30.

YOGARATNAM, N. AND SILVA, F. P. W. (1984). Effect of fertilizers on leaf composition of NPK in some *Hevea* cultivars (in press).

YOGARATNAM, N., SULAIMAN, H., KARUNARATNA, A. D. M. AND PERIES, K. S. A. C. (1976). Management of covers under *Hevea* in Sri Lanka. *J. Rubb. Res. Inst. Sri Lanka.* **54,** Part I No. 2, 291 - 298.

YOON, P. K. (1972). Further development in the establishment of three part trees. *Proc. Rubb. Res. Inst. Malaya Plrs'. Conf.* 1972, 73 - 82.

YOON, P. K., LEONG, W. AND MOHD GHOUSE (1976). An approach to modify branching habits its effects and potentials. *Plrs'. Conf. Rubb. Res. Inst. Malaya* 1976, 143 - 176.

DISCUSSION

Q — KINGSLEY GOONETILLEKA : DR. N. Yogaratnam did not discuss the subject of timing of fertilizer application in mature rubber. The RRISL recommendations are that fertilizers should not be applied after July. Our experience in the past had been that manure to mature rubber is applied twice a year ; first after wintering and the next in the latter part of the year. The present recommendations are that we should fertilize after wintering and the 2nd application should be done before end of July. The reason being according to RRISL research recommendations that little or no uptake of nutrients take place after July. Could you please clarify this ; as we are of the opinion that the nutrients are required to give maximum support towards the end of the year to produce heavy crops in November, December, January in which months we get 40% of the total crop. Further we feel that during wintering the tree requires maximum resources to produce a good leaf canopy after wintering. So please enlighten us on this important aspect of manuring.

A — N. YOGARATNAM, R.R.I. Sri Lanka. We have been doing some experiments with regard to time of application of fertilizer to mature rubber, comparing three times of fertilizer application ; at defoliation, at refoliation and after the leaves have hardened which is approximately 3 — 4 months from refoliation. This study very clearly showed that fertilizer is taken up very efficiently when applied at defoliation as well as at refoliation. On the basis of this, we recommend and this is in line with the Malaysian recommendations that fertilizer for mature rubber should be applied at the time of refoliation. If it is two, at the time of refoliation and the 2nd application should go in before the leaves have hardened which is about 2 — 3 months from the time of refoliation.

APPLICATION RATES OF FERTILIZER FOR IMMATURE RUBBER IN REPLANTED AREAS

By

K. PANMANEE, P. SUWANMONGKOL, L. NUALSRI, S. WINYARAT, Y. LIMCHITI AND S. POTHIWATHUTHAM

(*Rubber Research Centre of Songkhla, Thailand*)

ABSTRACT

Studies on different rates of application of compound fertilizer at 50,75,100,125 and 150% of the ORRAF recommended rate (100%) on the growth of immature rubber in both plantings with budded stumps (type 1 planting) and seed at stake (type II planting) under the smallholding conditions are reported. The results showed that all the various rates of compound fertilizer did not give significant differences in girths during the first 2 years; the rates of 100%, 125% and 150% did not show significant differences in girths from 2 to 6 years but they were markedly different from the lowest rate. These trials indicated that the normal rate of fertilizer application as recommended by ORRAF was considered appropriate for immature rubber for type I planting that allows the trees to reach tappable size within 6 years on Khlong Thom and Phuket series of fine-loamy mixed and fine clayey kaolinitic soils, respectively. In another trial with type II planting on Hat Yai Series of fine-clayey skeletal kaolinitic soil, the trees did not reach tappable size when they were 5 years old after budding in the field (or when they were released from the replanting programme). The trees still failed to reach tappable size even though higher rates of the fertilizer had been applied. In conclusion it is suggested that an extra round of fertilizer application at the recommended rate should be given to the trees at 5½ years age. This could possibly bring the trees to tappable size in the sixth year after budding.

INTRODUCTION

The accelerated replanting programme to replace the old and low yielding trees with high yielding clones has been increased to 50,000 hectares per year since 1974 (Panyalakshana, 1974). Under the accelerated programme the money from cess alone could not meet the cost of replanting of such a large extent of replanted areas. The Office of Rubber Replanting Aid Fund (ORRAF) Ministry of Agriculture and Cooperatives, was given the first loans by the World Bank and Commonwealth Development Corporation, which, including Thai Government budget, brought the total amount to 158 million US dollars (3,200 million Baht). It was estimated that about 35% of the total or 55·3 million US dollars equivalent to 1,120 million Baht was spent on fertilizer alone for immature rubber. It has been noticed that there are a large number of acres of replanted rubber released yearly from ORRAF at 5½ years old, these trees are found to be under the standard girth. This might be caused by insufficient fertilizer applied to immature rubber. In addition, these rubber trees have not received any further fertilizer for 1 – 1½ years after release from ORRAF, till the time of tapping. Many smallholders start tapping these under sized trees almost immediately after release from ORRAF. Most of these trees suffer from excessive tapping and damage at the beginning of production.

The experiments are aimed to clarify the problem involving the present fertilizer recommendations in respect of the suitable rate of fertilizer application compared to growth rate and economics for immature rubber on different types of soils, under smallholding conditions.

MATERIALS AND METHODS

Four experiments were carried out in 1977 in smallholdings selected on different soil series. The experiments were laid out in randomized complete blocks with four replications and five rates of fertilizer, namely 50,75,100,125 and 150% of normal rate (100%) of treatment (Appendix 1). Planting material of RRIM 600, the high yielding clone, was used in these experiments. The details of the experiments are as follows :—

Experiment	*Expt. No. 1*	*Expt. No. 2*	*Expt. No. 3*	*Expt. No. 4*
Location	Sabayoi	Sadao	Sabayoi	Sadao
Soil series*	Khlong Thom fine-loamy mixed, Typic Paleudults	Phuket clayey kaolinitic, Typic Paleudults	Khlong Thom fine-loamy mixed Typic Paleudults	Hat Yai clayey-skeletal, kaolinitic Typic Paleudults
Planting material	Budded stump (type I planting)	Budded stump (type I planting)	Budded at stake (type II planting)	Budded at stake (type II planting)
Date of planting	Oct. 1977	Sept. 1977	Nov. 1977	Nov. 1977
Cut back	—	—	Sept. 1978	July 1978
Plot size	24×35 m²	$38{\cdot}5 \times 35$ m²	24×40 m²	35×35 m²
Trees/plots	40	55	40	50
Recorded trees	30	27	32	24

* Appendix 2

During the immature period, a compound fertilizer 10 - 16 - 9 - 2·5 was used from planting up to 42 months old, then a mixture of 14 - 4 - 9 (ammonium sulphate 21%N, rock phosphate 25%P_2O_5 and potassium 60%K_2O) was applied upto 66 months old. Cover crops were normally established with a mixture of *Calopogonium mucunoides*, *Centrosema pubescens* and *Pueraria phaseoloides* at 6 : 3 : 1 by weight. Rock phosphate (36%P_2O_5) was regularly applied to the covers during the first 3 years after planting.

Before planting, 120 g of rock phosphate (36%P_2O_5) was thoroughly mixed with sub soil in the planting hole both planted with budded stumps (type I planting) and planted with germinated seeds for field budding (type II planting). The compound fertilizer of 10 - 16 - 2 - 2·5 was applied to seedlings at 2, 5 and 8 months old at the rate of 100 g per hole each time for the type II planting. The rates of compound fertilizers applied as treatments were started after cut back following the same schedule for both types of plantings (Appendix 1). During the first 18 months. fertilizer was broadcast around in circle for each tree. From 18 months onwards, fertilizer was broadcast over the whole clean weeded planting strips. Weeds were regularly controlled both by hand and weedicides before and after manuring.

RESULTS

Growth of rubber trees planted with budded stumps or type 1 planting

Results showed that in the first 2 years, the rates of fertilizer application at 50, 75, 100, 125 and 150% of the present recommended rate did not give significant differences in the girth of rubber trees, grown on Khlong Thom and Phuket series soil of fine-loamy mixed and clayey kaolinitic Typic Paleudults, respectively. After the tree was 2 to 6 years old, it was found that at the lower rates of fertilizer (50,75%) the trees grew slowly, girths were significantly different from those of the normal (100%) and higher rates (125% and 150%) of fertilizer application (Tables 1 and 2). Girth increment of each year was found to be not significantly different among the treatments except from 24 — 36 months old, as in Experiment 1 (Tables 5 and 6). The normal and higher rates tended to give better girth increments than the lower rates. However, the girth and girth increment of the trees treated with normal and higher rates were similar and allowed the tree to reach tappable size within 6 years on both Khlong Thom and Phuket series soil (Tables 5 and 6). This clearly showed that the amount of fertilizer applied at 100% of the present recommended rate of ORRAF is sufficient for the growth of immature rubber for type I planting.

Table 1. *Effect of the different rates of fertilizer application on growth of RRIM 600 of type I planting, (Expt. No. 1)*

Treatment	Girth (cm)					
	18 m	24 m	36 m	48 m	60 m	72 m
50%	10·2	14·5	24·7	34·6	43·1	50·4
75%	10·4	14·6	25·0	35·4	44·1	51·6
100%	10·4	14·8	25·6	36·0	44·8	52·0
125%	10·6	15·2	25·6	36·2	45·0	52·2
150%	10·4	15·1	25·9	36·4	45·4	52·3
Sig. diff.	NS	NS	*	**	*	NS
LSD ·05		—	0·5	0·9	1·3	—
·01		—	—	1·3	—	—
CV (%)	2·8	2·4	2·2	1·9	1·6	1·8

Table 2. *Effect of the different rates of fertilizer application on growth of RRIM 600 of type I planting (Expt. No. 2)*

Treatment	Girth (cm)					
	18 m	24 m	36 m	48 m	60 m	72 m
50%	8·9	12·7	19·7	29·5	39·7	46·6
75%	9·0	13·0	20·0	30·4	40·6	47·5
100%	8·7	13·2	20·2	30·2	41·0	48·2
125%	9·0	13·4	20·7	30·6	41·3	48·4
150%	9·0	13·4	20·7	30·8	41·5	49·0
Sig. diff.	NS	NS	NS	NS	NS	*
LSD ·05	—	—	—	—	—	1·4
CV (%)	4·1	3·9	4·0	3·6	2·4	1·9

Growth of rubber trees budded at stake or type II planting

Results of the first 2 years were similar to the type I planting showing that the rates of fertilizer application did not affect the growth of the trees. When the trees were older up to 3, 4 and 5 years after cut back, the trees treated with fertilizer at 100% and at higher rates of 125 and 150% were significantly different in girth from the lowest rate (50%) at P > ·05 except the 75% treatment. There were no marked differences among 100% and higher rates of treatments (Tables 3 and 4). Girth increment of each year gave a similar pattern to that of the type I planting. It is obvious that the higher rate of fertilizer application gave better girth increments than the lowest rate in the third year, and there is tendency to increase the growth in the fourth and fifth year on both Khlong Thom and Hat Yai series soil in Experiment 3 and 4, respectively (Tables 7 and 8). However, for type II planting, when the trees were 5 years old after cut back (or 6 years after planting germinated seeds in planting hole), even with the application of fertilizer at the highest rate, (150%), the trees did not reach tappable size, particularly on Hat Yai series soil which is gravelly clay under the lower layer. The girth at 5 years of age after cut back with the highest rate was 49·3 and 44·6 cm compared with 49·0 and 43·3 cm of the normal rate on Khlong Thom, fine-loamy mixed Typic Paleudults and Hat Yai clayey skeletal, kaolinitic Typic Paleudults, respectively. The extra round of the fertilizer applied after 5 years of age (or after release from the ORRAF) is discussed.

Table 3. *Effect of the different rates on growth of RRIM 600 of type II planting (Expt. No. 3)*

Treatment	Girth (cm)				
	18 m	24 m	36 m	48 m	60 m
50%	10·6	15·2	27·4	38·9	47·1
75%	11·2	15·8	28·2	40·0	48·6
100%	11·2	16·0	28·6	40·1	49·0
125%	11·5	16·6	29·7	41·4	49·7
150%	10·9	16·0	29·2	41·0	49·3
Sig. diff.	NS	NS	*	*	*
LSD ·05	—	—	1·30	1·4	1·5
CV (%)	3·8	3·5	2·9	2·2	2·0

Table 4. *Effect of the different rates of fertilizer application on growth of RRIM 600 of type II planting (Expt. No. 4)*

Treatment	Girth (cm) 18 m	24 m	36 m	48 m	60 m
50%	9·7	13·6	21·8	33·2	42·4
75%	9·7	13·7	22·0	33·5	42·9
100%	10·0	14·0	22·1	33·9	43·3
125%	10·2	14·2	22·6	34·9	44·3
150%	10·3	14·4	23·1	35·1	44·6
Sig. diff.	NS	NS	NS	*	*
LSD ·05	—	—	—	1·4	1·8
CV (%)	5·2	3·3	3·3	2·7	2·7

Table 5. *Girth increment of RRIM 600 of type I planting (Expt. No. 1)*

Treatment	Girth increment (cm) 24 m	24 - 36 m	36 - 48 m	48 - 60 m	60 - 72 m	72 m
50%	14·5	10·2	9·9	8·5	7·2	50·4
75%	14·8	10·2	10·4	8·7	7·4	51·6
100%	14·9	10·6	10·4	8·8	7·2	52·0
125%	15·2	10·4	10·6	8·8	7·2	52·2
150%	15·1	10·8	10·5	8·9	6·9	52·3
Sig. diff.	NS	*	NS	NS	NS	NS
LSD ·05	—	0·5	—	—	—	—
CV (%)	3·6	3·0	5·1	4·5	6·1	1·8

Table 6. *Girth increment of RRIM 600 of type I planting (Expt. No. 2)*

Treatment	Girth increment (cm) 23 m	24 - 36 m	36 - 48 m	48 - 60 m	60 - 72 m	72 m
50%	12·7	7·0	9·8	10·2	6·9	46·6
75%	13·0	7·0	10·4	10·1	7·0	47·5
100%	13·2	7·0	10·2	10·6	7·2	48·2
125%	13·4	7·3	9·9	10·6	7·2	48·4
150%	13·4	7·4	10·1	10·7	7·5	49·0
Sig. diff.	NS	NS	NS	NS	NS	*
LSD ·05	—	—	—	—	—	1·4
CV (%)	3·9	6·4	6·7	7·3	7·0	1·9

Table 7. *Girth increment of RRIM 600 of type II planting (Expt. No. 3)*

Treatment	Girth increment (cm) 24 m	24 - 36 m	36 - 48 m	48 - 60 m	60 m
50%	15·2	12·2	11·5	8·2	47·1
75%	15·8	12·4	11·7	8·6	48·6
100%	16·0	12·6	11·6	8·9	49·0
125%	16·6	13·1	11·7	8·3	49·7
150%	16·0	13·2	11·8	8·2	49·3
Sig. diff.	NS	**	NS	NS	*
LSD ·05	—	0·6	—	—	1·5
0·1	—	0·8	—	—	—
CV (%)	3·5	2·8	2·2	8·2	2·0

Table 8. *Girth increment of RRIM 600 of type II planting (Expt. No. 4)*

Treatment	Girth increment (cm) 24 m	24 - 36 m	36 - 48 m	48 - 60 m	60 m
50%	13·8	8·2	11·4	9·2	42·4
75%	13·7	8·3	11·5	9·4	43·0
100%	14·0	8·0	11·8	9·4	43·3
125%	14·2	8·4	12·3	9·4	44·3
150%	14·4	7·6	12·0	9·5	44·6
Sig. diff.	NS	NS	NS	NS	NS
CV (%)	3·3	6·1	3·8	3·8	2·7

DISCUSSION

The growth rate of a rubber tree is generally high during the second to fourth year after planting and will decrease later, till the tree reaches the tappable size. The results obtained from these experiments with the higher rates of fertilizer at 125% and 150% of the normal rate (100%) gave no marked difference in the growth rate of the tree after the fourth year. Similar results were noted even when the normal rates were doubled (Suwanmongkol and Panmanee, 1978). However the trees given the higher rates of fertilizer were not significantly different in girth and girth increment compared with the normal rate. These results confirmed that for type I planting the present rate of fertilizer recommended by ORRAF, which is the same as the normal rate (100%) in these experiments, is sufficient for growth of immature rubber, enabling the tree to reach tappable size in more or less 6 years (Fig. 1). Leaf analysis results on the basis of oven-dry matter showed no marked difference in element nutrients *e.g.* N,P,K,Ca and Mg among these treatments (Tables 9 and 10).

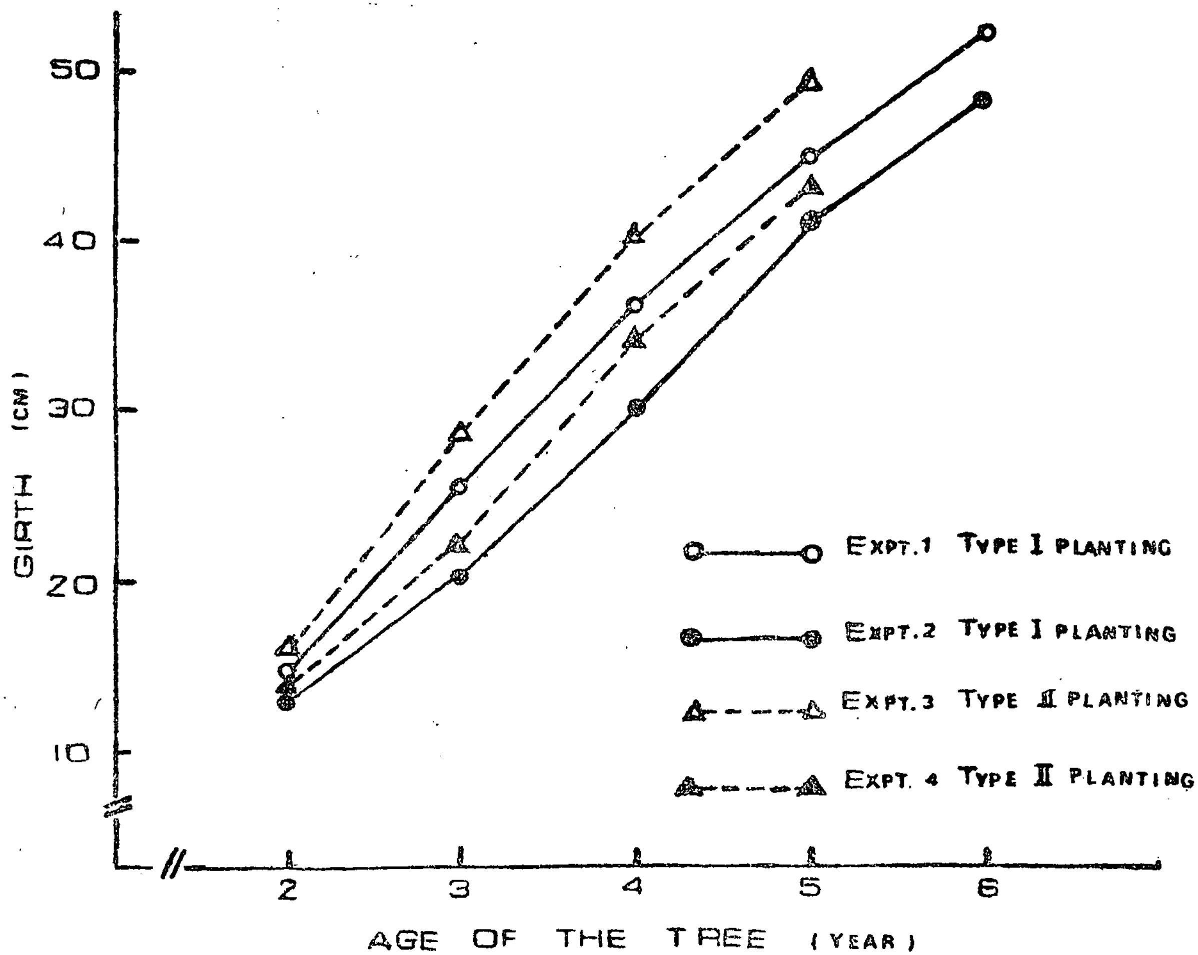


Fig. 1. Growth of RRIM 600 given the normal rate of fertilizer (100%).

Table 9. *Leaf nutrient content (% of dry matter) of RRIM 600 at 60 months old (Expt. No. 1)*

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn(ppm)
50%	3·22	0·19	0·83	0·56	0·31	245
75%	3·36	0·22	0·83	0·56	0·32	230
100%	3·21	0·22	0·83	0·55	0·32	262
125%	3·15	0·21	0·82	0·53	0·32	263
150%	3·38	0·23	0·85	0·58	0·30	261
Sig. diff.	NS	NS	NS	NS	NS	NS
CV (%)	4·7	7·0	6·7	9·1	8·1	9·9

Table 10. *Leaf nutrient content (% of dry matter) of RRIM 600 at 60 months old (Expt. No. 2)*

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn(ppm)
50%	3·64	0·26	0·77	0·61	0·37	262
75%	3·63	0·25	0·73	0·66	0·36	286
100%	3·67	0·25	0·81	0·58	0·33	215
125%	3·67	0·26	0·77	0·63	0·35	275
150%	3·70	0·26	0·79	0·57	0·33	271
Sig. diff.	NS	NS	NS	NS	NS	NS
CV (%)	6·2	8·4	7·3	10·5	9·5	17·3

For type II planting, the planting of germinated seeds or stock seedlings in the planting hole and subsequent budding at 8 - 9 months after planting, takes nearly 1 year before cut back and bud emergence. When the trees are 5 years old after cut back (6 years including planting of stock seedlings, which completed replanting, and are released from ORRAF) the trees had not reached tappable size, particularly in experiment 4 on Hat Yai series of the clayey skeletal kaolinitic, Typic Paleudults. The results indicated that even the higher rate of fertilizer application could not bring the trees to tappable size faster than the normal rate. Leaf analysis results at 60 months old again confirmed no marked difference among those rates (Tables 11 and 12). The mean girth of the tree was only 43·5 cm which was similarly reported in another fertilizer trial (Suvanmongkol *et al* 1983) on Kohong series soil, coarse loamy, siliceous, Typic Paleudults that the average girth of GT 1 was 44·3 cm at 5 years old after cut back of type II planting. However, the trees in experiment 4 had been given extra fertilizer at 60 months old and were brought to tappable size at about 72 months or 6 years old after cut back.

Table 11. *Leaf nutrient content (% of dry matter) of RRIM 600 at 60 months old (Expt. No. 3)*

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn(ppm)
50%	3·32	0·21	0·97	0·62	0·39	257
75%	3·42	0·23	0·97	0·69	0·37	291
100%	3·35	0·25	1·00	0·67	0·38	277
125%	3·48	0·24	0·97	0·64	0·38	305
150%	3·54	0·26	0·95	0·64	0·39	295
Sig. diff.	NS	NS	NS	NS	NS	NS
CV (%)	3·3	8·0	7·9	15·4	8·6	19·2

Table 12. *Leaf nutrient content (% of dry matter) of RRIM 600 at 61 months old (Expt. No. 4)*

Treatment	N (%)	P (%)	K (%)	Ca (%)	Mg (%)	Mn(ppm)
50%	3·40	0·23	1·12	0·60	0·34	168
75%	3·37	0·24	1·07	0·59	0·35	155
100%	3·46	0·25	1·08	0·59	0·35	164
125%	3·44	0·26	1·12	0·49	0·32	152
150%	3·48	0·25	1·07	0·56	0·34	179
Sig. diff.	NS	**	NS	NS	NS	NS
LSD ·05		0·01				
·01		0·02				
CV (%)	6·5	3·3	7·2	9·6	8·7	15·6

Saengruksawong *et al.* (1983) reported that the average girth of rubber trees, which were surveyed on the completely replanted smallholdings in 15 provinces, was about 42·2 cm, at release from ORRAF, at 5½ years old (or 47·5 cm at 9 months after release from the ORRAF). They also attempted grouping the trees of type II planting and found that the average girth of the trees was 44·0 cm at 6¼ years old or 75 months after cut back, which were not ready for tapping. In the replanting programme, the last fertilizer application to the trees was practically done at 54 months age after cut back when the last instalment of the grant was made. It is therefore suggested that the application of fertilizer to the trees at 60 months age is needed for girth increment. In addition, ORRAF (1983) made a similar survey to evaluate the growth of rubber trees of type I planting and found that the average girth of the trees at 5 years age was so small at 36·4 cm compared with 42·9 cm from the normal rate of fertilizer treatment in the experiments which received the same quantities as used at present by ORRAF. In view of the big variation between the girths of the experiments and of the survey, the differences may be due to many other factors involved rather than fertilizer alone, such as quantity and distribution of rain fall, soil conditions and agronomic management of the smallholders in each location. The soils used in these experiments are generally low in element nutrients like general soils in rubber growing areas. In the experiments, field upkeep and maintenance were done regularly, *e.g.* weeding was regularly done before and after fertilizer application, fertilizer was applied at the proper time as in the fertilizer programme. From this point of view, the smallholders may somewhat neglect field up keep and maintenance (Saengruksawong *et al*, 1983) resulting in poor growth. Therefore, ORRAF should introduce more effective measures to control and give strong advice more closely on field practice on the holdings.

CONCLUSION

1. During the first 2 years after planting, any rates of fertilizer application did not show significant differences in the girth of immature rubber for both type I planting (budded stumps) and type II planting (budding in the field).

2. After 2 to 6 years, the fertilizer rates at 100, 125 and 150% of the normal rate gave better girth increments which were significantly different from that of the lowest rate.

3. The normal rate (100%) recommended by ORRAF gave the same girth as the higher rates (125 and 150%). This shows that the present rate is adequate for the tree to be brought into tappable size at 6 years or a little over 6 years in type I planting, except for the experiment of type II planting on Hat Yai soil series, clayey skeletal, kaolinitic Typic Paleudults which would need an extra round of fertilizer application within at least another 6 to 8 months before being opened for tapping.

4. Under the present condition of replanted holdings, at least an extra round of fertilizer application would be needed and the holdings should be under further control of ORRAF for 6 months before releasing.

ACKNOWLEDGEMENTS

The authors wish to express their thanks to the rubber smallholders, the staff of ORRAF of Songkhla province for their assistance and best cooperation in these experiments, the staff of the Soil Science Division and Mrs Watana Panmanee for their help in chemical and data analysis. Mr Sutcharit Promdej for his suggestions during the preparation of this paper, Director of Rubber Research Centre and the Director of Rubber Research Institute of Thailand for their support and permission to present this paper. Finally the authors also wish to thank Miss Montha Aemnual for typing the manuscripts.

REFERENCES

OFFICE OF RUBBER REPLANTING AID FUND BOARD (1983). Survey of circumference of rubber at 5 years of type I planting. *The Ministry of Agriculture and Cooperatives, Bangkok*, 1983.

PANYALAKSHANA, P. (1974). The importance of acceleration to increase production and development for replanting. *Proc. of the seminar on acceleration of rubber production and development in Thailand, Songkhla, Thailand.* 15 - 17 May 1974.

SAENGRUKSAWONG, C. *et al* (1983). Growth of rubber trees after completed replantings programme, *Rubber Research Centre of Songkhla's seminar, Rubber Research Institute, The Department of Agriculture, Thailand,* December, 1983.

SUWANMONGKOL, P. AND PANMANEE, K. (1978). Study on the three rates of fertilizer for immature rubber. *16th Technical Conference, Kasetsart University Bangkok,* 3 - 5 February 1978.

SUWANMONGKOL, P. AND PANMANEE, K. (1983). Response of immature *Hevea brasiliensis* to NPK and Mg fertilizer on Kohong series soil. *Progress report* 1983.

APPENDIX 1

Schedule of fertilizer applications for different treatments

Time of application after bud emergence (month)	Quantity (g/tree)				
	A	B	C	D	E
2	50	75	100	125	150
5	50	75	100	125	150
8	75	112·5	150	187·5	225
12	100	150	200	250	300
15	100	150	200	250	300
18	100	150	200	250	300
24	150	225	300	375	450
30	150	225	300	375	450
36	150	225	300	375	450
42	150	225	300	375	450
48	200	300	400	500	600
54	200	300	400	500	600
60	200	300	400	500	600
66	200	300	400	500	600
Amount of fertilizer to 42 months	1,075	1,612·5	2,150	2,687·5	3,225
and 48 — 66 months	800	1,200	1,600	2,000	2,400
Total	1,875	2,812·5	3,750	4,687·5	5,625

A : 50% of the normal rate
B : 75% of the normal rate
C : 100% of the normal rate as the present recommendation
D : 125% of the normal rate
E : 150% of the normal rate

APPENDIX 2

Table 13. *Shows soil analysis results of pre-treatment (mean of sub plots)*

Location	Depth (cm.)	pH	Exchangeable cations (meq/100g) Ca++	Mg++	K+	CEC (meq/100g)	C %	O.M %	N %	Available (ppm) P	K	Texture	Soil series
Expt. No. 1 Sabayoi	0 - 15	4·6	0·52	0·44	0·20	4·68	0·94	1·62	0·06	19·9	32·4	Sandy loam	Khlong Thom, fine-loamy
	15 - 30	4·5	0·10	0·08	0·14	4·50	0·66	1·18	0·04	6·9	21·2	Sandy clay loam	mixed, Typic Paleudults
Expt. No. 2 Sadao	0 - 15	4·4	0·39	0·19	0·06	3·86	0·63	1·14	0·06	6·2	36·8	Sandy loam	Phuket, clayey Kaolinitic,
	15 - 30	4·4	0·28	0·14	0·05	3·65	0·55	0·95	0·06	5·1	32·8	Sandy clay loam	Typic Paleudults
Expt. No. 3 Sabayoi	0 - 15	4·2	0·26	0·36	0·16	5·97	0·94	1·62	0·07	10·5	26·2	Sandy loam	Khlong Thom fine-loamy
	15 - 30	4·2	0·10	0·08	0·10	5·25	0·54	0·94	0·04	5·5	13·6	Sandy clay loam	mixed, Typic Paleudults
Expt. No. 4 Sadao	0 - 15	4·5	1·14	0·56	0·10	5·96	0·81	1·40	0·07	5·1	52·0	Sandy loam	Hat Yai, clayey-skeletal,
	15 - 30	4·5	1·07	0·49	0·09	6·19	0·75	1·36	0·07	5·0	48·6	Sandy clay loam	kaolinitic Typic Paleudults

THE EFFECT OF MAJOR NUTRIENTS ON THE PHYSIOLOGY OF LATEX PRODUCTION

By

M. K. S. A. SAMARAWEERA
(*Rubber Research Institute, Sri Lanka*)

ABSTRACT

The latex yield of a rubber tree is increased when potassium is applied to the soil. Attempts are being made to understand this phenomenon, and the emphasis is on the physiology of latex production.

Sucrose is the carbohydrate precursor for latex production and its glycolysis is regulated by the enzyme invertase. Thus, the availability of sucrose and the invertase activity in latex producing tissues are the two important factors that determine the cropping potential of a tree. This enzyme is activated by K and higher activities are seen at high pH. K is known to have a positive effect on the transport of sucrose.

Using isotope techniques we have studied the effect of K, on the mobilities of other mineral ions, especially that of Ca which is relatively immobile in the phloem and is essential for the stability of membranes and tissues. When Ca is applied to the incisions made in the bark its transport to latex producing tissues is via ion-exchange sites and higher rates are seen at increased amounts of K. Despite the very high concentration of naturally occurring Ca in lutoid fraction when compared with that of the serum, most of the externally applied Ca is accumulated in the lutoides. The upper limit of the Ca that could be accommodated in the cytoplasm is governed by the composition of its organic acids.

When stimulants are applied to rubber trees changes are seen both in the concentration of Ca and the pH of the serum.

Thus, the cropping potential, adaptability to an exploitation system, and the incidence of brown bast of rubber trees grown under different agroclimatic conditions can be predicted by studying the latex, particularly the cytoplasmic serum.

INTRODUCTION

The fluid that is secreted when the bark of a healthy rubber tree is wounded is called latex and its physical properties are given in Table 1. Tupy (1968 and 1973a) has shown that sucrose is the precursor for latex production in rubber trees. Mineral ions such as K^+, Ca^{2+}, Mg^{2+}, organic acids and colouring matter such as carotene are also found in latex. When latex, collected without damaging its structure, is centrifuged at low temperature and high speed, its contents get separated into a few phases. The three main components are the rubber cream, the serum and the lutoid fraction and Table 1 gives an account of their occurrence in latex from healthy trees.

Table 1. *Physical data of latex*

Density	=	0.92 g/ml
Total solid content	=	40%
Serum volume	=	0.5 ml/ml of latex
Lutoid volume	=	0.1 ml/ml of latex

The first step in the biosynthesis of latex from sucrose in rubber trees is the conversion of sucrose into simple sugars by the enzyme invertase. Tupy (1973b) and Jacob *et al* (1982) have found that the activity of this enzyme is inhibited by Mg^{2+} and activated by K^{+}. Giaquinta (1983) has given a detailed account of the other beneficial effects of K, particularly on the transport of sucrose in plants. Tupy and Primote (1976) have reported that when rubber trees are intensively tapped or heavily stimulated there will be an inadequate supply of sucrose needed for basic biological functions of latex producing vessels, and sucrose deficiency is the cause for the incidence of " brown bast ".

In general the stability and permeability of a membrane depend on the calcium status and the stability of the cell wall is greatly decreased at low concentration of calcium. Thus the premature senescence of bark tissues which is the initial stage of latex vessel degradation, that leads to the physiological disorder brown bast in rubber trees, could also be associated with the calcium status of the phloem.

We report here our studies on the content of calcium and sucrose, and the transport of K and Ca in latex producing tissues in the rubber tree.

MATERIALS AND METHODS

Radioactive materials

^{45}Ca and ^{86}Rb used were purchased from the Radiochemical Centre, Amersham, England.

Plant material

Regularly ½ S, d/3 tapped trees from a 1976 replanting at Eladuwa State Plantation were selected for uniformity of growth and yield. There are three clones and they are :

Clone A — high yielding and highly susceptible to the physiological disorder brown bast.

Clone B — medium yielder, can stand intensive tapping and popular among the growers.

Clone C — average clone and its performance lies between A and B.

Application of radioactive materials

The trees were tapped by the conventional methods in the evening of the day before the application of radiotracers. There were at least three trees receiving the same treatment. In the early morning, horizontal grooves were made in the bark, using a sharp tapping knife, until the pale yellow layer of phelloderm was exposed. Special care was taken not to injure the vessels that carry latex. The grooves were either 2 cm or 5 cm in length. Solutions containing radioactive material (0·5 μCi / μl) were applied at the rate of 20 μl for the smaller and 50 μl for the larger grooves. When a solution is applied at the above rate, most of it is rapidly absorbed and to minimise the evaporation, the wound was covered with a piece of polythene, using petrolatum grease as the glue.

Analytical methods

Sucrose contents were determined by "the anthrone method" using a Corning colorimeter 253.

K and Ca contents were determined by atomic absorption spectrometry using a Varian Techtron AA — 6 system, fitted with an air-acetylene flame.

The radio - activity in ^{86}Rb and ^{45}Ca treated samples were assayed employing a TM Analytic Delta 300 liquid scintillation system and the counting efficiency was measured by "external standard channels - ratio method".

Collection of latex by conventional tapping

Latex samples were collected either into plastic cups containing small amounts of 25% ammonia or into vials placed in ice.

Collection of latex by micro-tapping

The bark of the tree was pierced with a pin and the flow of the latex was guided using a mini-gutter. Latex samples were collected into vials either placed in ice or containing small amounts of 25% ammonia. When the required amount of latex was collected a pin was placed in the hole to prevent further dripping.

Preparation of TCA extracts for the determination of mineral ions (K and Ca) and sucrose contents of latex

A sample of latex (1·0 ml) was diluted with 0·1% ammonia (4·0 ml) and 10% trichloroacetic acid (TCA) (2·5 ml) was added to this. The resulting mixture was kept in a refrigerator overnight and filtered. The filtrate, known as the TCA extract, was used for the analysis. Another latex sample (1·0 ml) of known fresh weight was dried at 85°C to a constant weight and cooled in a desiccator and the dry weight was recorded.

TCA extracts to determine total radioactivity in latex

A sample of latex (10 — 20 drops) collected by micro-tapping was diluted with 0·1% ammonia (4·0 ml) and 10% TCA (0·4 ml) was added to this. The resulting mixture was left in a refrigerator overnight and filtered. The filtrate was mixed with a suitable volume of scintillation solution and its radioactivity was assayed. When TCA was added the rubber coagulated, the coagulum was dried and the dry weight recorded.

These two procedures are summarised in Fig. 1.

Method for the study of radioactivity in different fractions of latex

Ice cold 0·4 M manitol (0·8 ml) was added to a latex sample (10 — 20 drops) collected in a centrifuge tube placed in ice, the contents were mixed and centrifuged at 12000 rpm for 15 minutes. During the process the latex is separated into three phases namely the rubber, the serum and the lutoid. The serum thus obtained is not very clear. The rubber was removed and the serum was transferred into another centrifuge tube using a syringe. After adding 1% Triton — X (1·0 ml) the lutoid particles were ruptured by placing the tube on a vortex mixer. The contents were mixed with scintillation solution and the radioactivity of the lutoid fraction was assayed. 10% TCA (0·5 ml) was added to the serum and the resulting mixture was kept in a refrigerator overnight and filtered. The radioactivity of the filtrate was assayed. The procedure is summarised in Fig. 2.

Experiment I

Distribution of mineral ions in different components of latex

Latex from healthy trees were collected into vials placed in ice, centrifuged at 40,000 rpm and mineral ion contents in each phase were determined after destructing the organic matter by using perchloric acid : nitric acid (1 : 3) mixture.

Experiment 2

Mineral nutritional and sucrose status of rubber trees

Six trees from each of the clones A, B and C were conventionally tapped (½S, d/3), latex samples were collected and the contents of mineral ions and sucrose were determined. The changes with time in the tree trunk were studied by analysing the latex samples collected by micro-tapping at different intervals from six different places of the tree trunk. Three trees from each clone were used and samples were collected from the following places.

1. the middle point of the virgin bark immediately under the tapping cut.

2. the point 20 cm vertically below point 1

3. the point 40 cm vertically below point 2

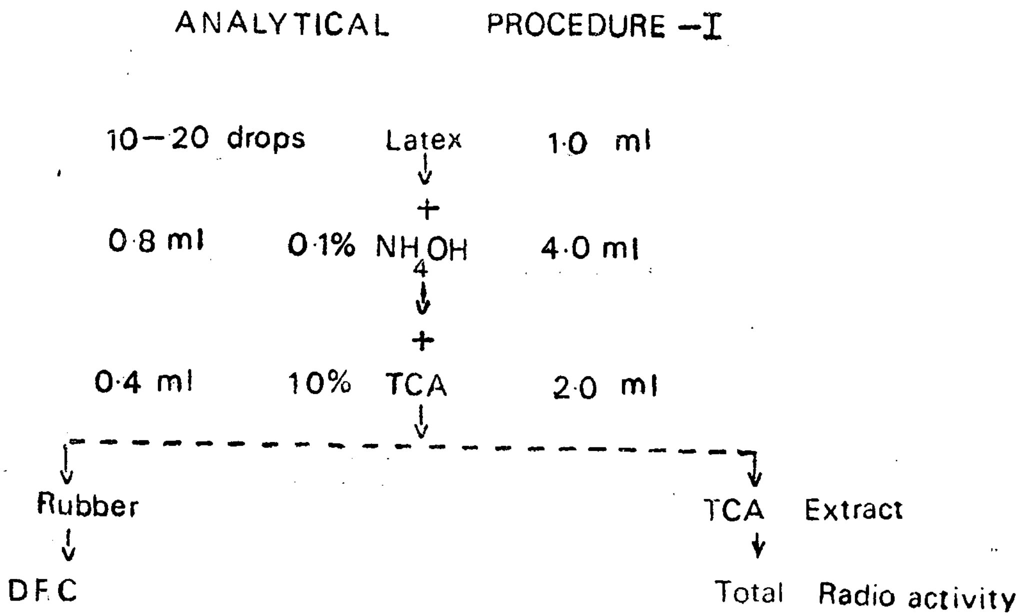


Fig. 1. **Summary of procedure**

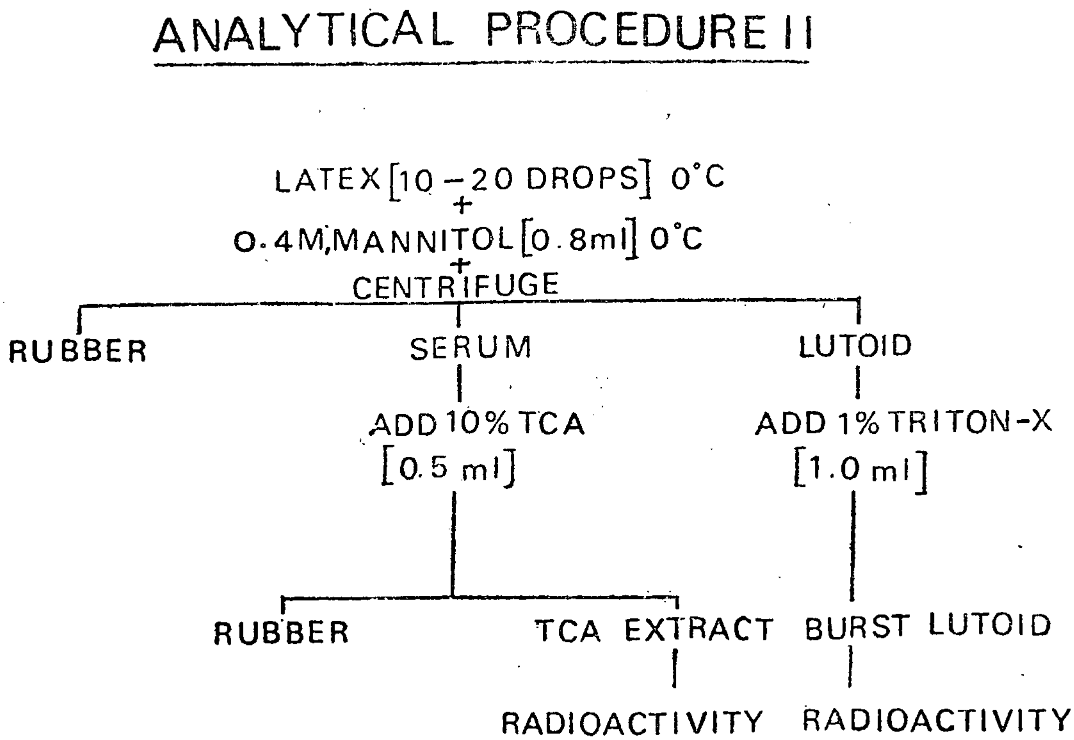


Fig. 2. Summary of procedure (II)

4. the point diagonally opposite to the middle point of the bark under renewal, on the other panel.

5. the point 20 cm below point 4

6. the point 40 cm below point 5

Experiment 3

Kinetics of K uptake

Five equally spaced incisions (2 cm in length) were made in the virgin bark immediately below the tapping cut with one at the mid-point of the tapping cut. Four more incisions, vertically separated by 5 cm from the closest incision were made in the virgin bark below the middle point of the tapping cut. Thus there were nine incisions per tree and Fig. 3 illustrates the positions of the incisions in the tree. ^{86}Rb solutions containing different amounts of K and Rb (10^{-3}, 10^{-2} and 10^{-1} Mol/l) were applied to the cuts, latex samples were collected at regular intervals by micro-tapping and the total radioactivity in them was determined. The experiment was replicated on three trees.

Experiment 4

Fate of externally applied K

^{86}Rb solution, 10^{-2} M with respect to K and Rb was applied into three incisions (5 cm in length) on the virgin bark below the tapping cut (see Fig. 4 for details). Latex samples were collected 4 h after application of radioactive material, by micro-tapping, and the distribution of Rb in different phases were studied. Then the trees were conventionally tapped after 6 h, successive fractions of 20 ml of latex were collected and total radioactivity in each fraction was determined.

Experiment 5

Kinetics of Ca uptake

10^{-2} M Ca solutions containing fixed amount of ^{45}Ca and different amount of K were applied to incisions made in the bark, latex samples were collected at regular intervals by micro-tapping and the total radioactivity in them were determined.

Experiment 6

Fate of externally applied ^{45}Ca

A 10^{-2} M Ca solution containing ^{45}Ca and 10^{-2} M with respect to K was used in this study. The solution was applied into three incisions in the bark and latex samples were collected 72 h after application, by micro-tapping, and distribution of ^{45}Ca in different components was determined. Trees were then tapped, successive fractions of 20 ml of latex were collected and total radioactivity in each fraction was determined.

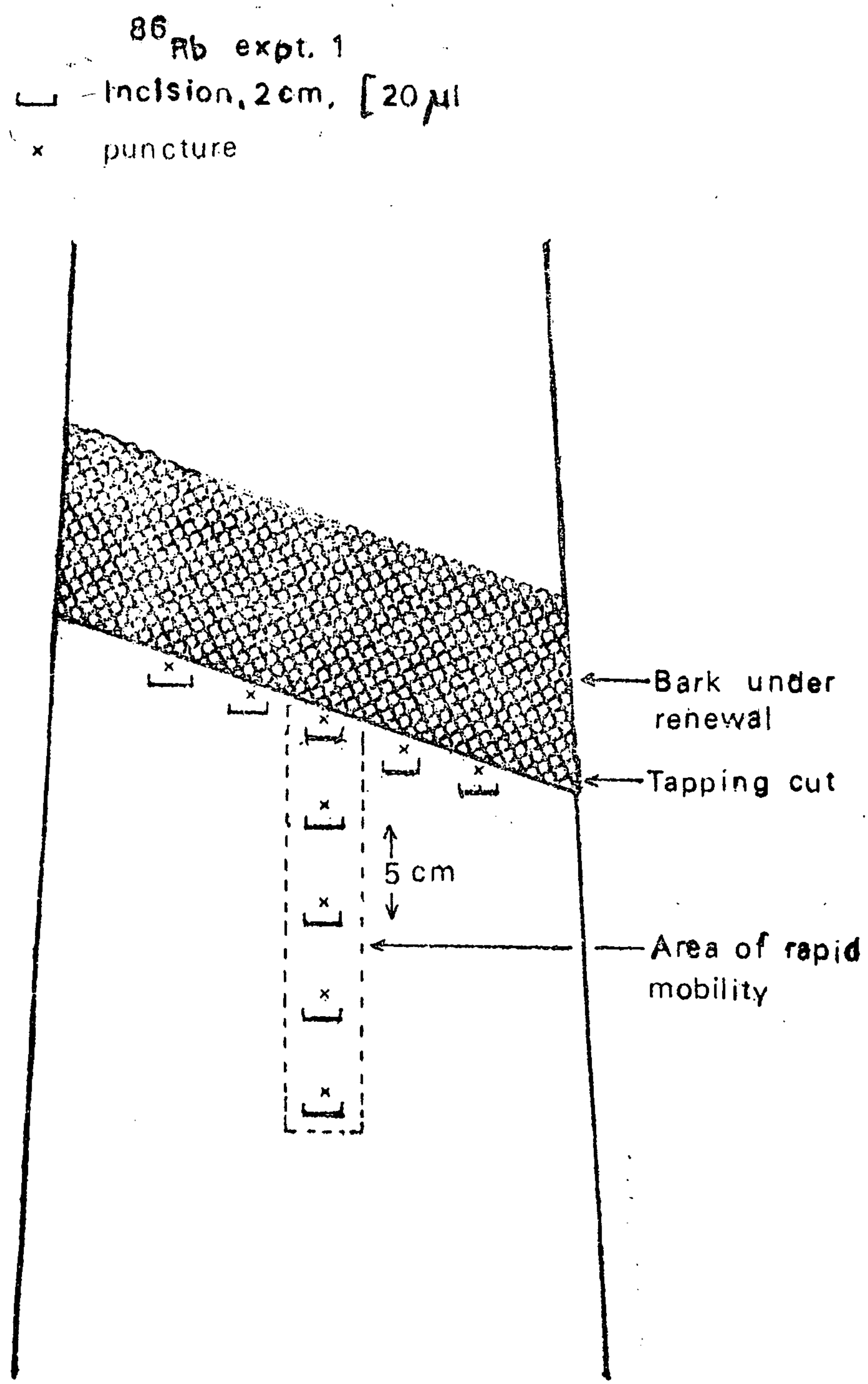


Fig. 3. Schematic representation of experimental trees

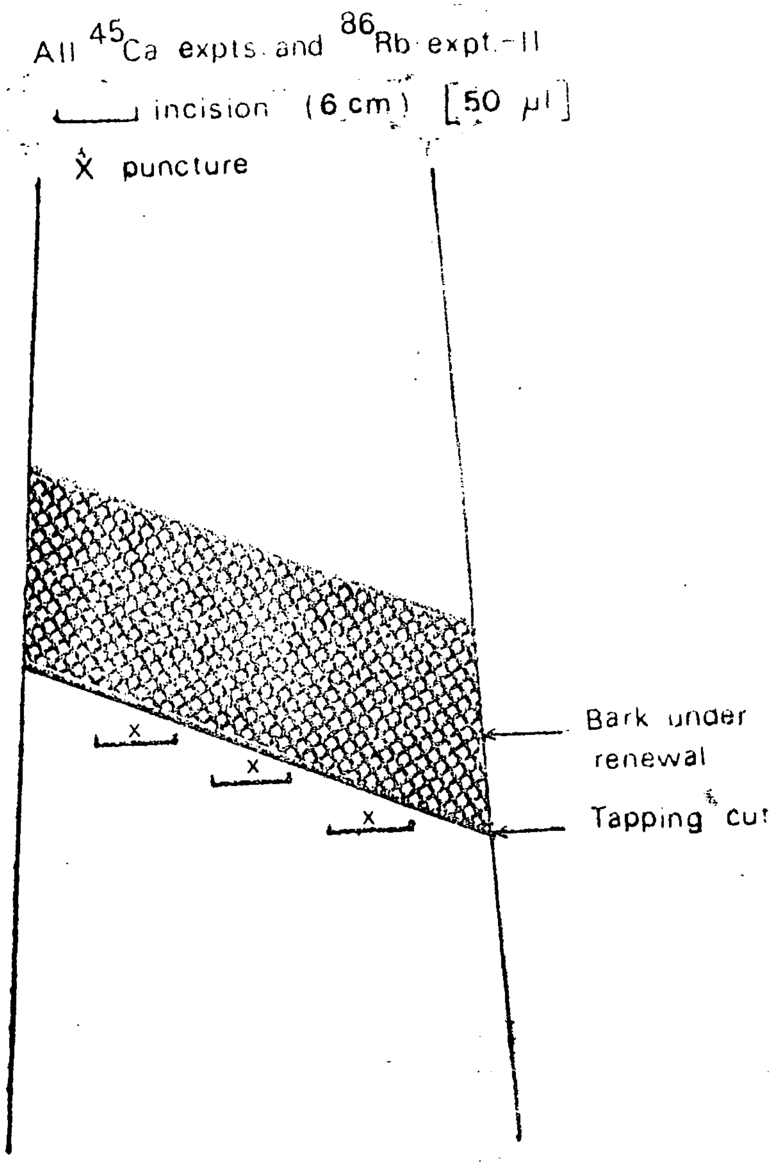


Fig. 4. Schematic representation of trees used for experiments 4, 5 and 6

RESULTS AND DISCUSSION

The composition of latex from different clones is given in Table 2 and there are significant differences in contents of calcium and sucrose. This is particularly so between the two clones A and B, and A and C. The brown bast susceptible high yielding clone A, has lower calcium and sucrose in latex than in the latex from B or C. Sucrose is the starting material for the biosynthesis of latex and in high yielding trees, the conversion is more efficient than in low yielding trees. Thus, in order to have a sufficient supply of sucrose to the latex producing vessels and to the area where there is a renewal of bark, the trees with low latex sucrose should be tapped at a low frequency. Whereas trees with high latex sucrose can be tapped at a high frequency or subjected to stimulation.

Table 2. *Composition of latex from different clones*

Clone	Concentration	
	Sucrose μmol/ml latex	Ca μg/ml latex
A	4.3	18.7
B	14.5	25.7
C	12.6	24.1
F	24.4***	8.7***
L S D (P=0.05)	1.7	4.0

There is a steady decline with time of the calcium content of latex samples collected at different points of the tree trunk. The calcium content of latex of clone A is always lower than that of clone B. Details are given in Fig. 5. A gradual decrease was not seen either in sucrose content or in potassium content. While both potassium and sucrose are mobile in the phloem, calcium is relatively immobile. Hence there is no rapid replacement of calcium, drained out from latex producing tissues. Thus, there is a localized calcium deficiency in the tissues near the tapping cut, (*i.e.* in the so called drainage area). Flint and Ramage (1935) have reported that the low viscosity of latex is linked with its low calcium content.

When a solution of ^{86}Rb was applied to the bark it was taken up rapidly and there was a steady increase in the radioactivity seen in latex samples collected by micro-tapping. An equilibrium state of the amount of ^{86}Rb penetrated was achieved within a short time (4 – 6 h) of application. Rapid and higher penetrations were seen in the area vertically below the mid-point of the tapping cut (see Fig. 3). The uptake of ^{86}Rb increases with the increasing concentrations of K in solution (see Fig. 6).

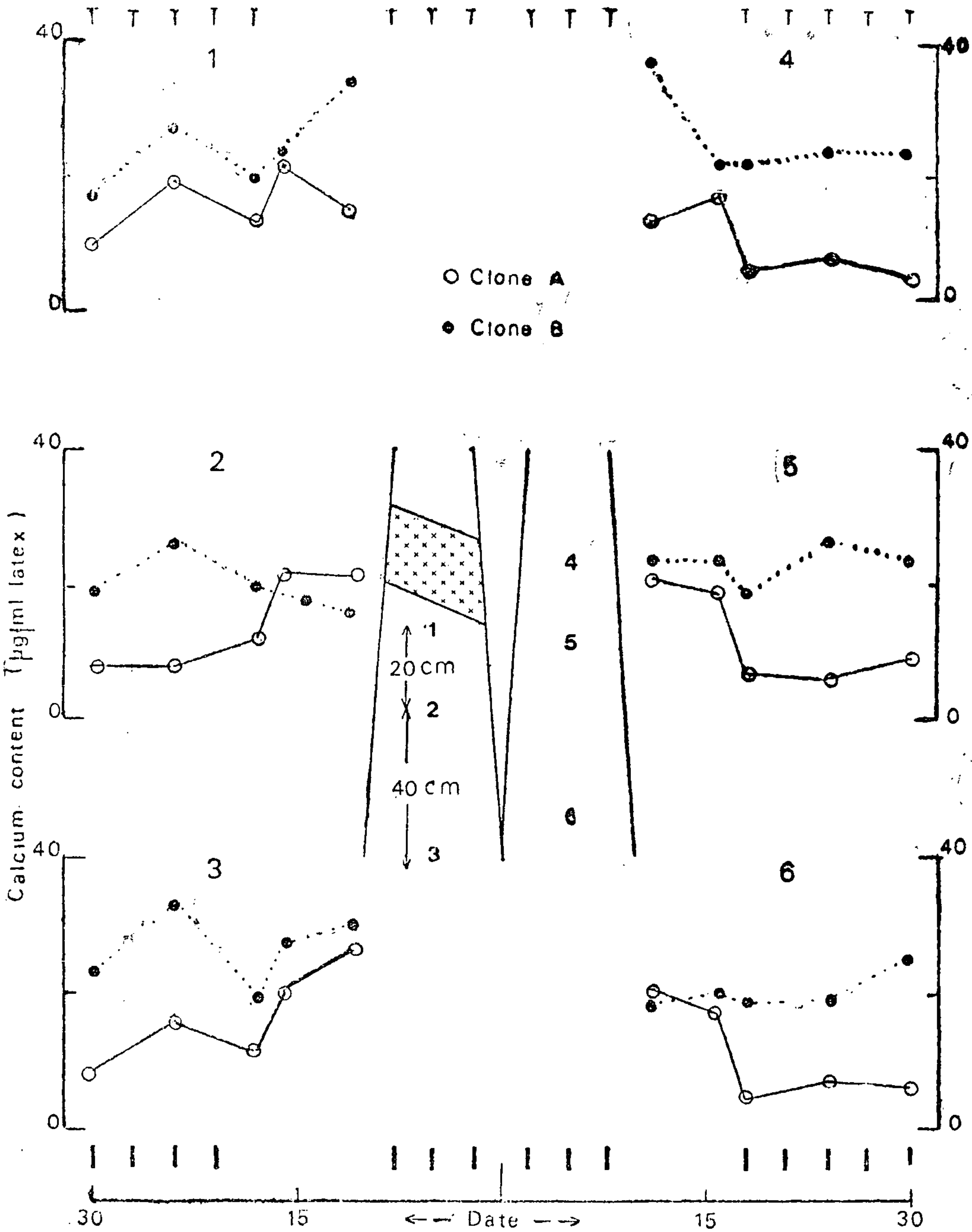


Fig. 5. Changes with time of the calcium content of the tree trunk (vertical lines indicate the tapping cut).

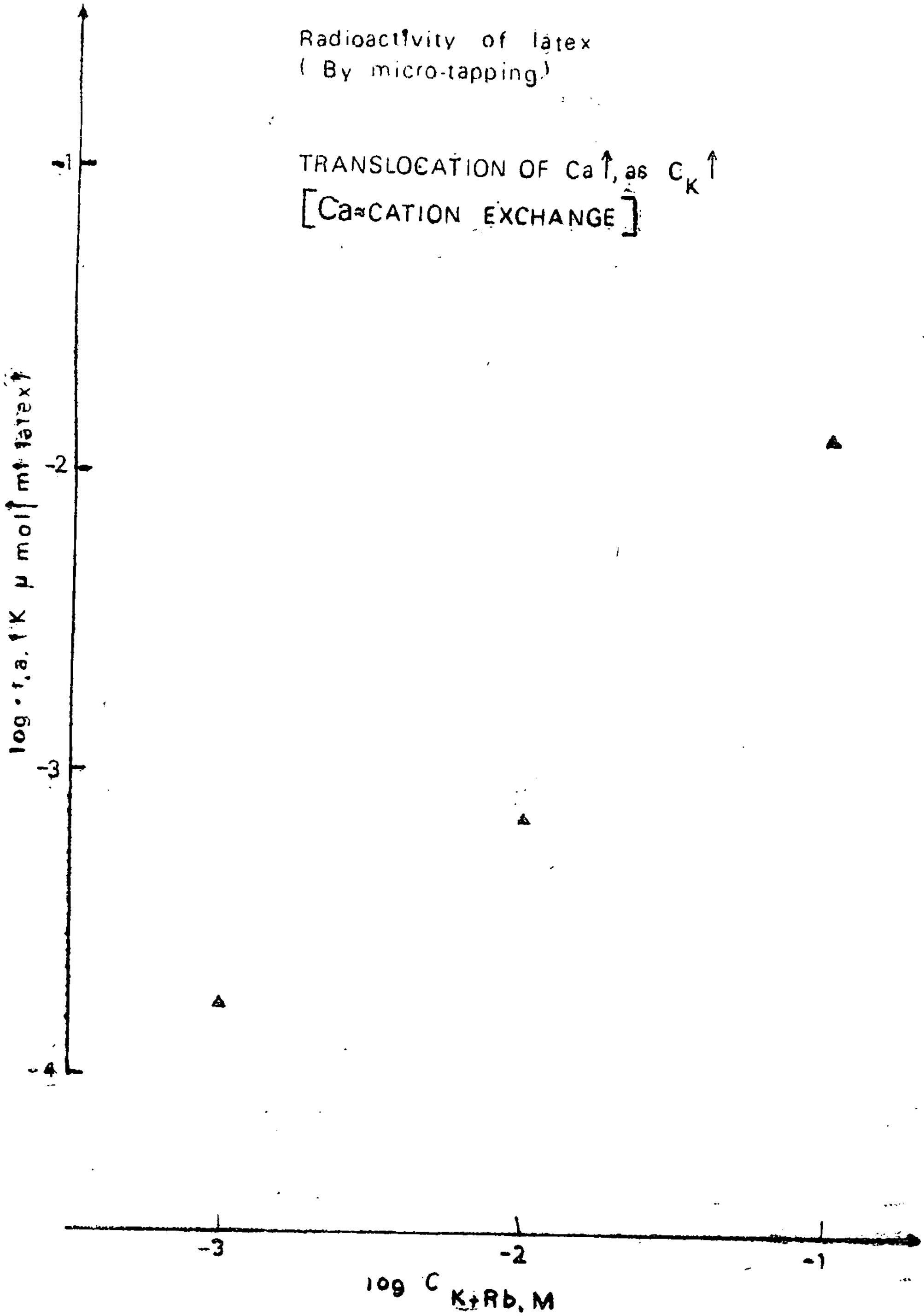


Fig. 6. Variation of ^{86}Rb content of latex with the change of K concentration in solution

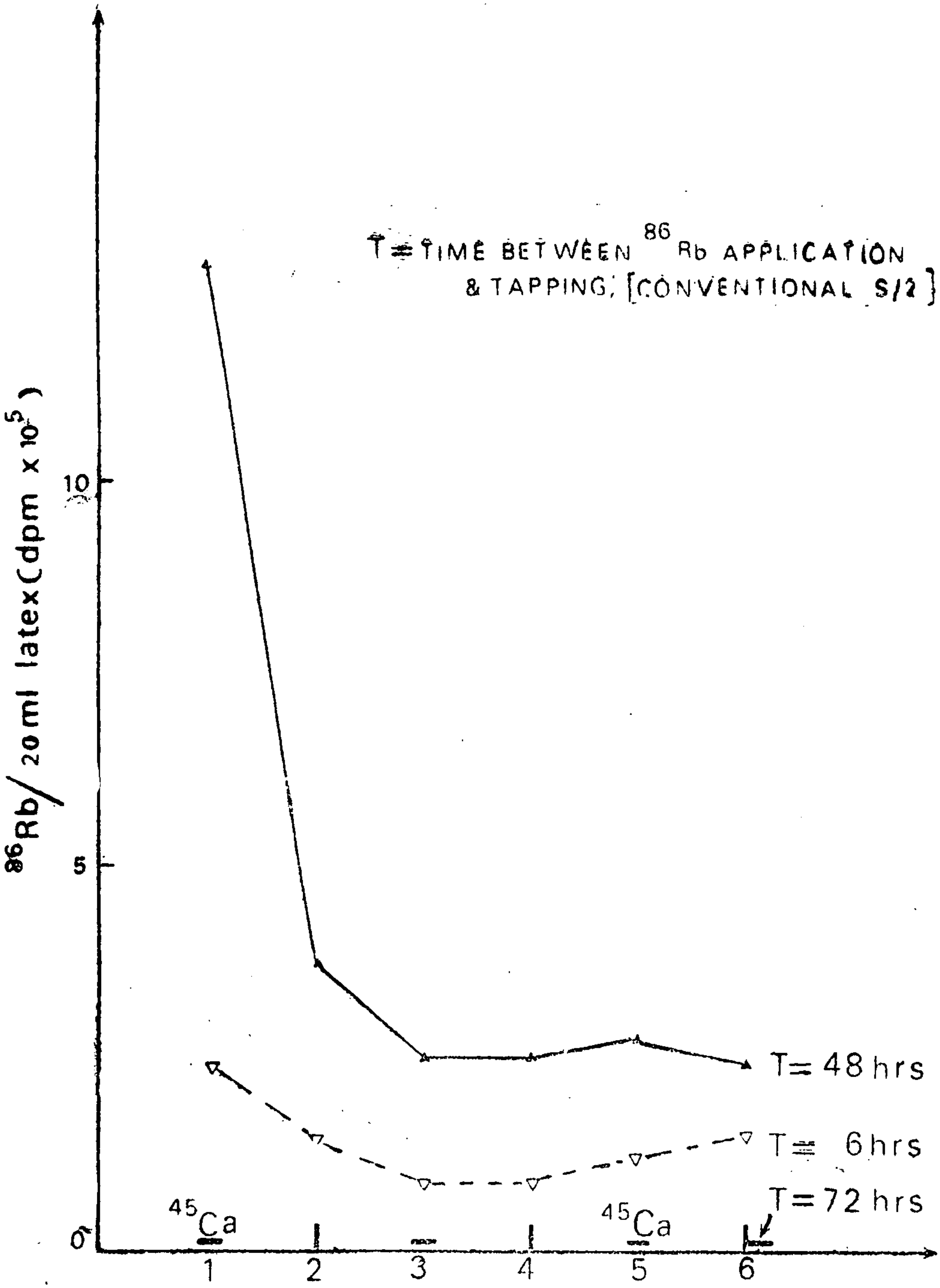


Fig. 7. ^{45}Ca and ^{86}Rb content in successive fractions of latex.

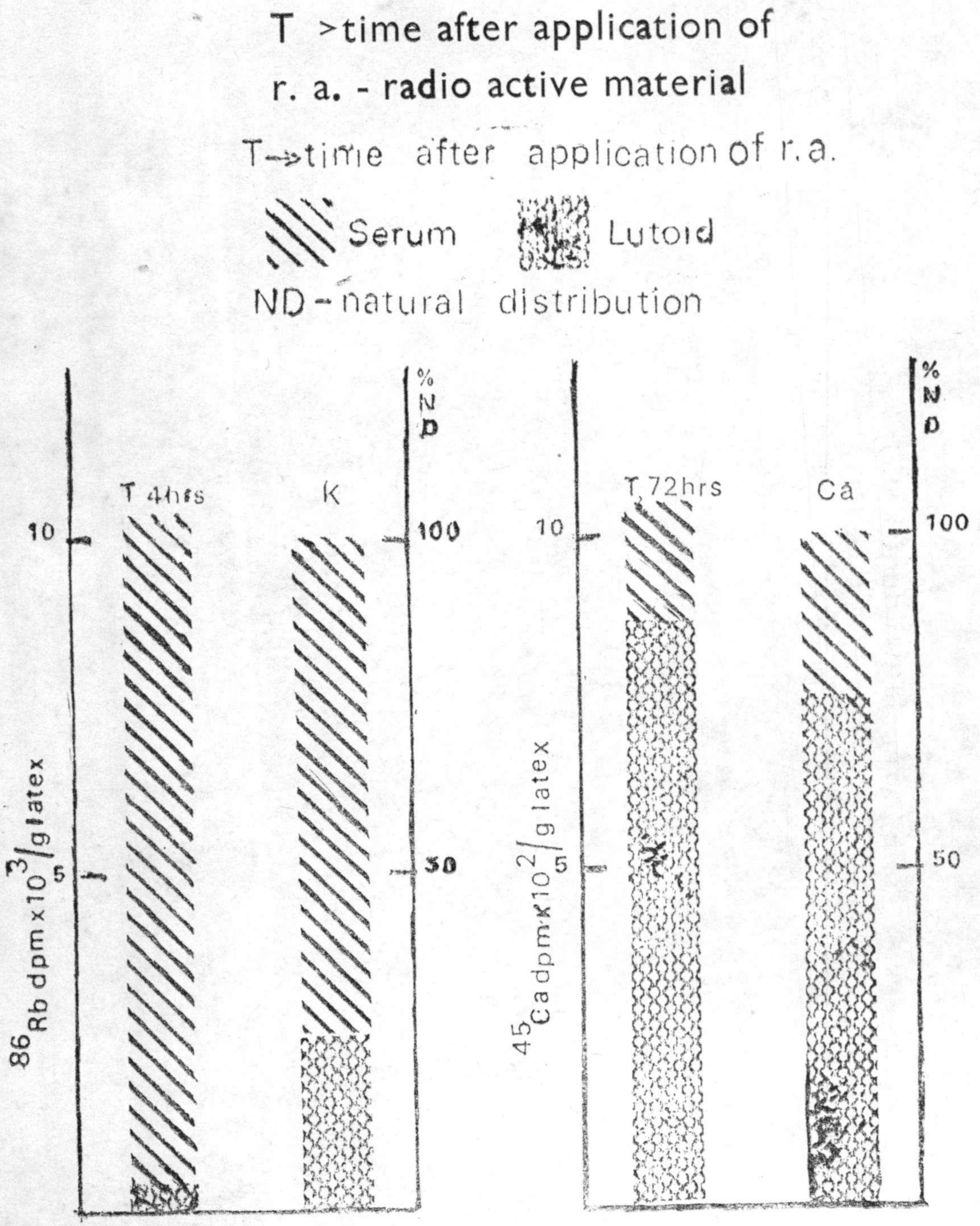


Fig. 8. Distribution of Ca, K and radioactivity in different fractions of latex

When the trees are conventionally tapped 6 h after bark application of ^{86}Rb, the radioactivity was equally distributed in all successive (20 ml) fractions collected during the flow of latex. However, when the trees are tapped 48 h after bark application, very high concentration of ^{86}Rb was seen in the first fraction (see Fig. 7).

Very slow and low uptake of ^{45}Ca was seen when latex samples collected by micro-tapping were assayed. The amount of radioactivity seen in successive fractions of latex collected by conventional tapping of trees after 72 h of application was also very low. It was also noticed that the mobility of Ca increases as the K concentrations in ^{45}Ca solution increases. This confirms that there are ion exchange sites in the bark and movement of Ca^{2+} is via these sites.

Physical data of latex (in Table 1) show that lutoid particles occupy a small portion (10%) of the total volume of latex. The actual volume of fluid (water) in the lutoid is much smaller than that. Lutoids are the vacuoles of the cytoplasm. The amount of K in serum is much higher than that in lutoid and thus the concentrations of K in both these media are in the same order. However, both the amount, and the concentration of Ca in lutoid are much higher than those in the surrounding medium, the serum (please refer Table 3). It can be seen from Fig. 8, that most of the externally applied K remains in the serum. But a greater proportion of Ca moves into the lutoid. This movement of Ca is against the concentration gradient thus it requires metabolic energy.

Table 3. *Distribution of mineral ions in different fractions of latex.*

Element	Content [ugm/ml, latex]		Concentration [ug/ml]	
	Serum	Lutoid	Serum	Lutoid
K	1050	350	2000	3000
Ca	6	18	11	170

Pate (1976) has discussed in detail the compositions of exudates from phloem and xylem. The phloem exudates are alkaline and contain soluble carbohydrates, organic acids, organic phosphates, inorganic ions (both cations and anions) and nitrogenous solutes. Hence the calcium content in the serum (*i.e.* the soluble fraction of the phloem exudate) is near its point of saturation or ultimate limit. Thus, it cannot accommodate in soluble form, any more of externally applied calcium, and therefore it is difficult to correct any localized deficiency of this element.

Cultural practices such as tapping, stimulation and fertilizer application that could change the composition of cytoplasm should have to be carefully studied. This is particularly so because it is very important to have adequate amounts of calcium and sucrose in the area, where there is latex production and bark renewal.

CONCLUSION

Traditionally, the selections in a breeding programme or adaptability to an exploitation system of rubber trees grown under different agroclimatic conditions are done by studying the vigour, growth rate and latex yield. It is also important to consider the changes with time in the composition, particularly the contents of the sucrose and calcium, of latex samples collected from different locations of the tree trunk. This information could be used to predict the cropping potential and the incidence of " brown bast ".

ACKNOWLEDGEMENTS

I wish to thank Dr O. S. Peries, the Director, Rubber Research Institute of Sri Lanka, for the interest shown, Messrs W. C. Dayaratne, A. M. A. Perera and Miss C. K. Maheepala for skilful technical assistance, the International Atomic Energy Agency and the Canadian International Development Agency for financial assistance. Thanks are also due to Mr K. P. Perera, the Superintendent, Eladuwa State Plantation, for his hospitality during the course of this work.

REFERENCES

FLINT, C. F. AND RAMAGE, H. (1935). Note on the ash composition of rubber latex, *Abs. Chem. Ind., Lond.* **54**, 337.

GIAQUINTA, R. T. (1983). Phloem loading of sucrose, *Annual Review of Pl. Physiol.*, **34**, 347 - 387.

JACOB, J. L., PREVOT, J. C. AND d'AUZAC, J. (1982). Physiological activators of invertase from *Hevea brasiliensis* latex. *Phytochem* **21**, 851 - 853.

PATE, J. S. (1976). Nutrients and metabolites of fluids recovered from xylem and phloem : Significance in relation to long distance transport in plants in *Transport and transfer processes in plants.* Eds. Wardlaw, I. F. and Passioura, J. B. 253 - 281.

TUPY, J. (1973b). The regulation of invertase activity in the latex of *Hevea brasiliensis* Muell. Arg. The effects of growth regulators, bark wounding, and latex tapping. *J. exp. Bot.* **24**, 516 - 524.

TUPY, J. AND RESING, W. L. (1968). Anaerobic respiration in latex of *Hevea brasiliensis* substrate and limiting factors. *Biologia Pl.* (Praha) **10**, 72 - 80.

TUPY, J. (1973a). The level and distribution pattern of latex sucrose along the trunk of *Hevea brasiliensis* Müell, Arg. as affected by the sink region induced by latex tapping. *Physiolgie Vegetale* **11**, 1 - 11.

TUPY, J. AND PRIMOT, L. (1982). Sucrose synthetase in the latex of *Hevea brasiliensis.* Muell, Arg. *J. exp. Bot.* **33**, 988, 995.

Q — D. D. JAYASOORIYA : Please let me know the relationship between potassium and calcium with regard to plugging index and tree coagulation of latex.

A — M. K. S. A. SAMARAWEERA, R. R. I. Sri Lanka : What we studied here is something different from what Mr. Jayasooriya is asking. This is a more general question and I think we could discuss it later.

A — N. YOGARATNAM, R. R. I. Sri Lanka : There is a physiological relationship between calcium and potassium. High levels of K inhibits the uptake of calcium and vice versa. This happens in the soil and it happens in the tree also. All these may contribute to the relationship between plugging index, and calcium and potassium levels in the tree and in the soil.

A — M. K. S. A. SAMARAWEERA, R. R. I. Sri Lanka : The definition of plugging index and the whole process of physiology has to be considered in answering this question. This paper concentrates more on the mobilities and partitioning of nutrients. What is interesting is that we have found that when potassium is applied into the bark together with calcium, the mobility of calcium is increased. We are discussing a localized deficiency. This is a little bit different from what Mr. Jayasooriya wants to know.

Q — K. SIVAPALAN, TRI Sri Lanka : Just a word of caution on these isotope studies. I think is isotope studies it should be remembered that in applying, exogenously applied substrates, they need not necessarily follow the obligatory pathways of metabolism and distribution. In other words if you apply the substrate and as you apply, its distribution need not be necessarily the distribution of the particular nutrient when taken up from the soil through photosynthesis.

A — M. K. S. A. SAMARAWEERA, R. R. I. Sri Lanka : That question will be there. But we were interested in why there is a calcium gradient in certain clones ? If we were to apply 45 Ca to the soil do not think the 45 Ca in the whole world would be sufficient to study a mature rubber tree. So this was a small scale study of the rubber tree. Otherwise you can never do it.

Q — K. SIVAPALAN : But do your results really represent what is actually happening in the plant.

A — M. K. S. A. SAMARAWEERA, R. R. I. Sri Lanka : Yes. What is happening is when you apply calcium it goes into the lutoid. Situation is, that you get localized deficiencies because what is in the lutoid is not in an available form.

A — N. YOGARATNAM. Calcium is known to be a peculiar element and its immobility in the phloem of tree crops is well known. In apple, there is a deficiency disease called bitter pit. Researchers have been working on this for several years but have still not solved this problem. This is because calcium is not mobile in the phloem. Dr. Samaraweera tried at least to see how this could be sorted out even though a real problem in trying to study calcium mobility in the tree, due to the very low mobility of this element in the tree.

A — M. K. S. A. SAMARAWEERA, R. R. I. Sri Lanka. The relative mobilities of calcium and potassium were clearly seen in the two slides.

Q — SAMARAWICKREMA, Peenkande : Regarding application rates of fertilizer for immature rubber in replanting areas you were referring to planting type 1 and planting type 2. Could you kindly enlighten on that.

A — Type 1 is budded stumps. Type 2, seedlings.

MINERALISATION OF UREA COATED WITH NEEM CAKE AND TAR AND ITS EFFECTS ON GROWTH OF RUBBER

By

M. KARTHIKAKUTTY AMMA, S. NARAYANAN POTTY, ANTHONY P. ANTONY AND K. S. KRISHNAKUMARI

(*Rubber Research Institute of India, Kottayam, South India*)

INTRODUCTION

Out of the three major plant nutrients used as fertilizers, nitrogen ranks first and its efficient use has been the subject of study since the dawn of scientific agriculture. In India nitrogen constitutes about three-fourth of the total fertilizer consumption. However, its efficiency is only less than 50 per cent under the agro-climatic conditions prevailing in our country. Urea has become the most popular nitrogenous fertilizer because of its low unit cost, high nitrogen content and easy availability. When applied to soil, urea gets easily hydrolysed resulting in nitrification and leaching losses (Allison, 1966). The use of chemicals like N-serve (pyridine derivative) and AM (pyrimidine derivative) as nitrification inhibitors were reported by numerous workers (Gasser, 1965 ; Prasad, *et al*, 1971). But most of these chemicals are costly and have to be imported. This necessitated testing of cheaper and indigenously available materials as nitrification inhibitors and alcohol extract of neem seed, neem cake and tar were found to have this property (Bains *et al*, 1971 ; Muthuswamy *et al*, 1975 ; Patil, 1972 ; Yeoh and Soong, 1979). The present work was undertaken to study the effect of neem (*Azadirachta indica L*) cake coated and tar coated urea on the growth of budded stumps and to study the mineralisation pattern of these coated forms when applied to rubber growing soils.

EXPERIMENTAL

Pot culture experiment

A green house experiment in glazed pots was conducted with the soil collected from the RRII farm. The characteristics of the soil are pH 4·5, organic carbon 0·8%, Bray II extractable phosphorus 2·4 mg/100g ; morgan extractable potassium 3·5 mg/100 g and magnesium 0·80 mg/100 g. Three doses of urea (5·0 g, 7·5 g and 10·0 g) were tried in the experiment. There were ten treatments:

1. 5·0 g urea neem coated
2. 5·0 g urea tar coated
3. 5·0 g urea without coating
4. 7·5 g urea neem coated
5. 7·5 g urea tar coated
6. 7·5 g urea without coating
7. 10·0 g urea neem coated
8. 10·0 g urea tar coated

9. 10·0 g urea without coating
10. Control (no nitrogen)

All the treatments were replicated thrice.

Twenty g of coal tar was melted in a beaker and dissolved in 30 ml kerosene oil and 250 g of neem cake powder was added and mixed thoroughly. To this 1000 g urea were added and thorough mixing was done with a glass rod. For preparing tar coated urea, urea was directly added to the melted tar-kerosene mixture and mixed well.

The treatments were incorporated 75 days after planting the budded stumps. Regular watering and recycling of leachate were done. Soil samples were collected at 15, 45 and 75 days after incorporation of fertilizers. The samples were analysed for ammoniacal-N and nitrate-N (Black, 1965). Periodic height and girth measurements were also recorded. The plants were uprooted 12 months after planting and dry matter production determined.

Incubation study

500 gm of air dried soil passing through a 2 mm seive were taken for the study. Urea at the rate of 100g N/kg soil was thoroughly mixed with the soil. There were four treatments (neem cake coated, tar coated, uncoated and a control without nitrogen). The treatments were replicated seven times. The soil was kept at field capacity throughout the period of study by adding distilled water. The beakers were incubated at room temperature for 37 days. 10 g samples were drawn at periodic intervals and analysed for ammoniacal and nitrate-N (Black, 1965).

RESULTS AND DISCUSSION

Pot culture experiment

Mean height, diameter and dry matter production of the plants under various treatments are given in Table 1. Application of urea coated with neem cake and tar at 7·5 and 10·0 g per plant resulted in a significant increase in height and diameter. However, at the lowest level viz., 5·0 g, the effect was not significant. Favourable effect of coating on dry matter production was observed only for neem cake applied at 10·0 g. Increase in dose of uncoated urea from 5·0 to 10·0 g did not significantly increase the growth attributes. On the other hand, increase in height of 29·6 cm and 29·0 cm was observed due to increase in dose of neem and tar coated urea from 5·0 to 10·0 g. Corresponding figures for diameter increase were 2·84 and 2·66 mm, respectively. Neem cake and tar have been found to be equally efficient as far as their effect on growth is concerned. From these results it is clear that the efficiency of urea nitrogen on growth of rubber plants can be improved by coating urea with neem cake or tar. Favourable effect of rubber coated fertilizers on growth of rubber plants has been reported from Malaysia (Yeoh and Soong, 1979). Growth and yield of many crops have also been reported to be increased by the application of coated fertilizers and nitrification inhibitors (Bains *et al*, 1971 ; Muthuswamy *et al.*, 1975 ; Patil, 1972 ; Subbiah *et al*, 1979).

Table 1. *Effect of coating on growth of budded stumps*

Treatments		Height (cm) April '82	Diameter (mm) July '82	Dry matter g/plant July '82
5·0 g	urea-neem	97·00	15·40	477·8
5·0 g	urea-tar coated	93·3	15·11	440·8
5·0 g	urea	94·00	14·83	411·7
7·5 g	urea-neem	116·7	17·90	568·8
	Urea-tar	115·7	17·54	532·6
	Urea	95·7	14·97	488·5
10·0 g	urea-neem	126·7	18·24	608·6
	Urea-tar	122·3	17·77	579·2
	Urea	100·3	15·15	504·4
Control		63·3	11·81	240·1
	SE	6·37	0·70	28·5
	CD	18·86	2·07	84·3

Soil samples drawn from pot culture experiments at 15, 45, 70 days showed that ammonium-N was higher in the first sampling and decreased as the crop growth advanced (Table 2). Reduction in ammonium-N after 15 days might be due to its nitrification and plant uptake. Significantly higher ammonium-N values were observed for uncoated urea over coated forms in the first sampling. At 5 g level, soil treated with uncoated urea registered 195·33 ppm of ammoniacal-N, while soil treated with neem cake and tar coated urea had only 72·66 ppm and 149·33 ppm, respectively. At a subsequent sampling coated forms retained higher ammonium-N than uncoated urea. On the fifteenth day, release of ammonium-N from neem cake coated urea was lower than tar coated urea. On the other hand, ammonium-N was higher in neem coated urea treated pots on the 45th day. This brings out that neem cake and tar when used for coating urea are effective in slowing the process of ammonification, neem cake being superior. Similar results have been reported by several workers on the effect of neem cake (Muthuswamy *et al*, 1975; Patil, 1972 ; Subbiah *et al*, 1979) and coal tar (Bains, *et al*, 1971) in other crops.

Table 2. *NH_4 - N (ppm) in soil at various stages of growth*

Treatments		15 days	NH_4 - N 45 days	75 days
5·0 g	urea-neem	72·66	35·00	18·66
5·0 g	urea-tar	149·33	28·33	15·00
5·0 g	urea	195·33	12·66	11·00
7·5 g	urea-neem	150·00	41·33	21·00
7·5 g	urea-tar	165·66	36·00	19·33
	Urea	199·66	21·33	14·33
10·0 g	urea-neem	189·33	46·33	35·33
	Urea-tar	230·66	42·66	36·33
	Urea	269·33	26·33	20·66
	Control	·0	2·66	6·66
	SE	10·78	0·84	1·83
	CD	32·00	2·48	5·44

Incubation study

In the incubation study ammoniacal-N and nitrate-N were estimated at close intervals (Table 3). Ammonification was evident from the first day and attained a peak in 7 days in all the treatments and gradually decreased as the period of incubation advanced. Between the coated forms and uncoated forms of urea, a significant difference was noticed in all the observations. Till the 21st day of incubation, uncoated urea treated soil registered higher values of ammoniacal-N than neem and tar coated urea treated soil. Thereafter the soils treated with coated urea retained more of ammoniacal-N. From the second week onwards ammoniacal-N was more in neem coated urea, which indicates the beneficial effect of this material on controlled release of nitrogen from applied urea. These results confirm the observation on ammoniacal-N reported in pot culture experiment (Table 2).

Table 3. *NH_4 - N (ppm) at various periods of incubation*

Treatment	Days of incubation						
	1	4	7	14	21	28	37
Control	1·4	2·3	2·6	2·3	2·1	2·1	1·3
Urea	34·9	101·0	105·3	100·6	88·0	73·5	48·2
Urea-neem	19·6	60·6	98·6	92·6	78·7	77·8	70·5
Urea-tar	19·2	57·5	99·6	91·7	78·6	72·7	64·3
SE	0·23	0·72	0·78	0·85	1·53	1·40	0·73
CD	0·68	2·13	2·31	2·52	4·53	4·14	2·16

Nitrate-N at different periods of incubation are presented in Table 4. Indication of release of nitrate-N from applied urea could be detected only in the case of uncoated urea from the 14th day of incubation. Even though nitrification started by the 14th day appreciable nitrification was noticed only by the 28th day. In Munching series soil in Malaysia, nitrate-N was detected only after 28 days (Tan Keh Huat, 1982). Till the close of the incubation study, no appreciable release of nitrate-N was noticed in both the coated forms of urea. The absence of nitrification of applied urea in the coated forms could be attributed to the inhibitory effect of the coating materials on ammonification and nitrification.

Table 4. *NO_3-N (ppm) after various periods of incubation*

Treatments	Days of incubation						
	1	4	7	14	21	28	37
Control	1·4	1·8	1·8	2·2	2·4	2·2	3·3
Urea	1·6	1·8	2·5	10·7	18·1	37·9	41·0
Urea-neem	1·7	1·7	1·7	1·7	2·1	2·2	1·8
Urea-tar	1·6	1·8	1·4	1·6	2·1	2·1	2·5
SE	0·05	0·11	0·14	0·23	1·36	0·77	0·14
CD	0·15		0·41	0·68	4·03	2·28	0·41

The results of the pot culture and incubation studies indicate that both neem cake and tar are efficient in increasing the growth of plants by retarding nitrification as well as ammonification, when used as coating materials on urea. Even though neem cake coating is only marginally superior to tar coating on the growth of plants, the rate of ammonification is reduced significantly with neem cake coating. This justifies the use of neem cake along with tar as coating material for enhancing the efficiency of urea. Further investigations are required to find out whether repeated applications of coal tar treated urea at higher levels will have any phytotoxic effects on growth of rubber under field conditions.

ACKNOWLEDGEMENT

The authors are thankful to Dr M. R. Sethuraj, Director of Research, for the keen interest in the study and useful suggestions during the course of investigation.

REFERENCES

ALLISON, F. E. (1966). The fate of nitrogen applied to soil. *Advances Agron.* **18,** 219 - 58.

BAINS, S. S., PRASAD, R. AND BHATIA, P. C. (1971). Use of indigenous materials to enhance the efficiency of fertilizer nitrogen for rice. *Fertil. News.* **16,** 30.

BLACK, C. A. (1965). Methods of soil analysis. Part - 2, 1191.

GASSER, J. K. R. (1965). Effect of 2-Chloro (trichloro methyl) — pyridine on the nitrification of ammonium sulphate and its recovery by rye grass. *J. Agric. Sci.* **64,** 299 - 303.

MUTHUSWAMY, P., RAJUG, S. N. AND KRISHNAMOORTHY, K. K. (1975). Mineralisation of urea coated with nitrification inhibitors. *J. Indian Soc. Soil. Sci.* **23, 1 - 7.**

PATIL, N. D. (1972). Neem (Azadirachta indica L) oil as nitrification inhibitor. *Fertil. News.* **17,** 37.

PRASAD, R., RAJALE, G. B. AND LAKHADIVE, B. A. (1971). Nitrification retarders and slow release nitrogen fertilizers. *Adv. Agron.* **23**, 337 - 383.

SUBBIAH, S., RAMANATHAN, K. M., HONORAJ, J. FRANCIS AND KOTHANDARAMAN, G. V. (1979). Effect of neem cake blended urea on the yield and nutrient uptake of rice- *Madras Agl. Journal.* **66,** 789.

TAN KEH HUAT (1982). Studies in Malaysian Soils-II. Urea hydrolysis and transformations. *J. Rubb. Res. Inst. Malaysia,* **30,** 19 - 30.

THOMAS, J., PRASAD, R. (1982). Studies on mineralisation of neem and sulphur coated and N - serve treated urea. *Fertl. News,* **27,** 39 - 43.

YEOH, C. S. AND SOONG, N. K. (1979). Natural Rubber based slow release fertilizers. *J. Rubb. Res. Inst. Malaysia* **25,** 1 - 8.

SESSION 5. LEAF AND BARK DISEASES

DIFFERENCES IN CLONAL REACTION OF *HEVEA* RUBBER TO SOUTH AMERICAN LEAF BLIGHT

By

T. W. DARMONO

(*The National Centre for Rubber Research, Medan, Indonesia*)

ABSTRACT

Breeding of Hevea *rubber clones resistant to South American leaf blight* (Microcyclus ulei) *has been carried out since 1937 in Brazil. Clones now in commercial planting are high in production, but nevertheless susceptible to SALB. This is largely attributed to the occurrence of physiologic races of the pathogens. High yielding clones such as FX 3864 and RRIM 600 are both susceptible to races 1, 2, 3, 6 and 7* of Microcyclus ulei. *The poor yielding FX 349, on the other hand, is resistant to most of the races. Clones having one of the parents resistant to SALB, such as FX 2261 is susceptible only to race 1, FX 3199 to race 2 and IAN 717 to race 3. For more effective control of SALB, the race structure of* M. ulei *in the region should be taken into consideration. In addition, clones which bear the least number of spores are advantageous. Further advantage should be taken from the environmental conditions in that passage of the susceptible young foliage after wintering occurs during the dry season.*

INTRODUCTION

South American leaf blight (SALB) caused by *Microcyclus ulei* (P. Henn) Arx. is the most destructive disease of *Hevea brasiliensis* (Muell.) Arg. The disease was first found by Ule on wild *Hevea* in Brazil in 1900 (Holliday, 1970). Ten years later, it had become the primary cause of decreased yield of cultivated rubber (Hilton, 1955).

Plantings established in Suriname, Guyana and Trinidad in the early 1900's were a total failure because of the disease. The Ford Motor Company planted about 1200 ha in Fordlandia, Brazil in 1927, and by 1931 the disease had destroyed a quarter of the planting. Similar failures occurred in Panama, Costa Rica and Colombia. The disease is presently confined to Tropical America from 24°S in Brazil to 18°N in Mexico (Chee, 1975).

Having failed in Fordlandia, Ford opened up a new site at Balterra, further down the Tapajos river from Fordlandia, where 6400 ha were planted between 1934 and 1942. The high yielding Oriental clones were introduced into the planting.

Breeding for high yield and SALB resistance was started in 1937. *Hevea brasiliensis, H. benthamiana, H. pauciflora, H. spruceana* and *H. guianensis* were used in the breeding programme. Oriental clones were crossed with Neo Tropic clones involving first-crossing, double-crossing, back-crossing, out-crossing and second out-crossing in an attempt to produce clones having high yield and SALB resistance (Anon, 1971).

Table 1. *Synopsis of Hevea clones selected in Amazon basin from 1937 to 1968*

	FX	IAN	Other	Total
Hevea brasiliensis				
First crossing of Neo-tropic clones	239	814	—	1,053
First crossing of Neo-tropic and Oriental clones	2,885	429	—	3,314
Out-crossed to Neo-tropic clones	51	—	—	51
Double-crossing	3	4	—	7
Back-crossed to Neo-tropic parent	24	11	—	35
Out-crossed to Oriental clones	198	113	53	364
Second out-crossed to Oriental clones	—	15	—	15
Hevea benthamiana				
First crossing of Neo-tropic clones	—	227	—	227
Hevea brasiliensis X *Hevea benthamiana*				
First crossing of Neo-tropic clones	31	—	—	31
First crossing of Neo-tropic and Oriental clones	1,938	82	52	2,072
Double-crossing	1	323	69	393
Back-crossed to Oriental parent	22	1,340	1,264	2,626
Hevea brasiliensis X *Hevea benthamiana*				
Second back-crossed to Oriental clones	—	422	—	422
Out-crossed to Oriental clones	68	2,277	265	2,610
Second out-crossed to Oriental clones	4	50	3	57
Hevea brasiliensis X *Hevea pauciflora*				
First crossing of Neo-tropic and Oriental clones	—	—	395	395
Out-crossed to Oriental clones	—	—	1,570	1,570
Hevea guianensis				
First crossing of Neo-tropic clones	—	2	—	2
Hevea brasiliensis X *Hevea guianensis*				
First crossing of Neo-tropic clones	1	—	—	1
First crossing of Neo-tropic and Oriental clones	1	1	—	2
Hevea brasiliensis X *Hevea microphylla*				
First crossing of Neo-tropic and Oriental clones	1	—	—	1
Hevea benthamiana X *Hevea microphylla*				
First crossing of Neo-tropic clones	3	—	—	3
Hevea brasiliensis X *Hevea spruceana*				
First crossing of Neo-tropic clones	10	—	—	10
First crossing of Neo-tropic and Oriental clones	41	5	—	46
Illegitimate	80	225	15	320
		Total	..	15,626

Source : Anon (1971).

Over 15,000 clones were produced during 30 years since 1937. These clones are prefixed FX and IAN (Table 1). Selection was then continued in different places in Brazil producing clones with prefixes IAC, SIAL, AC, RO, AM and B, respectively from Sao Paulo, Bahia, Acre, Rondonia, Amazonas and Para (Anon, 1971). To-date, clones with high yield are all susceptible to SALB ; resistant clones are in general poor yielders.

Clones versus fungus

The occurrence of physiologic races of *M. ulei* was first reported by Langford in 1945. The hitherto resistant clones F 409 and F 1619 were found to be attacked severely by the disease in Santarem, in the state of Para, Brazil. Langdon (1965) found that clones having F 4542 genotype were susceptible to race 2, but not to race 1. Liyanage and Chee (1982) found only one race in Trinidad, possibly race 4 (Holliday 1970) or race 6 according to Chee and Darmono's unpublished information. However, the Trinidad race exists in two pathogenic strains in that the Neo Tropic clones were attacked by the virulent strain and the Oriental clones by the non-virulent strain.

Table 2 shows the reactions of some important clones in Brazil to races 1, 2, 3, 6 and 7 according to Darmono and Chee (1984). Clones having one of the parents resistant to SALB, such as FX 2261 (F 1619 × Avros 183), FX 3899 (F 4542 × Avros 368) and IAN 717 (PB 86 × F 4542) are susceptible to race 1, 2 and 3, respectively. IAN 710 and IAN 713, the two clones derived from F 409, were originally resistant to race 1, race 2 and race 3 of *M. ulei*. But when race 4 and race 5 appeared in the states of Amazonas and Para, respectively, these two clones then succumbed to infection. In Bahia, IAN 710 and IAN 713 were susceptible to race 6 (Darmono & Chee, 1984). Similarly FX 25 was one of the resistant clones selected by Ford. When it was widely planted in Brazil, it became susceptible to SALB.

Table 2. *Reactions of some important* Hevea *clones in Brazil to races of* Microcyclus ulei

	Planting scale in Bahia	Yield* kg/ha/year	Reaction to races**				
			1	2	3	6	7
FX 349	—	918	R	—	R	R	R
FX 3899	—	1,206	R	S	R	R	R
IAN 710	—	455	R	R	R	S	R
IAN 713	—	738	R	R	R	S	R
IAN 717	—	1,350	R	R	S	R	R
FX 985	Large	1,251	R	R	S	R	S
FX 2261	Large	1,251	S	R	R	R	R
FX 3844	Large	995	S	R	S	S	S
FX 3864	Large	1,899	S	S	S	S	S
FX 4163	Large	1,377	S	R	S	S	S
IAN 837	Small	1,386	S	R	R	R	S
FX 3846	Small	1,350	S	R	S	S	S
FX 4098	Small	1,175	S	R	S	S	S
FX 25	Experimental	891	R	S	S	S	S
RRIM 628	Experimental	—	S	S	S	S	S

* Anon, 1971
**R, Resistant
S, Susceptible

These examples demonstrate that *M. ulei* mutate and produce a new race capable of attacking clones hitherto resistant to it. It seems however, host itself is not broken in its character of that becoming susceptible. Such property in the form of gene inherited from the parentages is possibly still be there and never changed without any natural pollination that was existing before. For the matter of that, IAN 710 and IAN 713 are still having no reaction to races 1, 2 and 3 whereas getting susceptible to races 4, 5 and 6. The fact that high yielding clones are susceptible to the disease and vice versa (Table 2) suggests that disease resistant genes are linked to genes of low yield, a phenomenon merits more detail investigation.

Regional differences of clonal susceptibility

The genus of *Hevea* is indigenous to South America. It occurs in the region of the Amazon river system, the Guianas, the Upper Orinoco and the Mato Grosso (Holliday, 1971). Since 1930's, it has distributed to other regions in South and Central America, to be followed by the spread of SALB. Langford (1946) first noted regional differences in clonal response to SALB. These differences as they occur in Brazil are shown in Table 3.

Table 3. *Regional differences in clonal susceptibility to South American leaf blight in Brazil*

	Bahia	Mato Grosso	Para and Amazonas
IAN 3810	R	R	R
FX 3925	S	R	R
IAN 717	S	—	R
FX 4098	S	R	S
IAN 710 & IAN 713	R	S	S

(Anon, 1971)

Brazil has a large expanse of land stretching from 5°N to 31°S. Rubber is cultivated in many states in Brazil under different climatic conditions. There are thus regional differences in clonal behaviour towards the disease. Disease escape for example, occurs when refoliation coincides with the dry season. For this reason, FX 25 in the state of Esperito Santo is free from infection. The Oriental clones PB 86, PB 186, RRIM 600 and Tjir 1 are commercially planted in Sao Paulo without much disease problem. This is because the low temperature and low rainfall experienced in Sao Paulo are not favourable for SALB.

The geographical distribution of races and pathogenic strains of *Microcyclus ulei* also influence the susceptibility of clones in the region. Clones IAN 710 and IAN 713 are mildly infected in Bahia but are very susceptible in Mato Grosso, Para and Amazonas. It may be that race 4 in Amazonas and race 5 in Para are more pathogenic than race 6 presents in Bahia. In Amazonas and Para, IAN 717 is relatively free of infection due perhaps to the absence of race 3.

Darmono and Chee (1984) found that FX 25 and IAN 710 were more susceptible in Bahia than in Trinidad; and that RRIM 600 was more resistant in Bahia than in Trinidad. This may be explained on the basis of differences in the occurrence of races and strains of *M. ulei* in different localities. The disease susceptibility of certain clones in different places therefore depends on at least three factors :

(1) The occurrence of physiologic races of *M. ulei*;

(2) The presence of pathogenic strains of the fungus and

(3) Regional climatic conditions in relation to disease epidemiology.

Disease development on different clones

The different stages of disease development on the leaves closely follow that of leaf age (Table 4). Leaf lesions as occurring in the field are either chlorotic or necrotic. Chlorotic lesions appeared at the conidial stage and early pycnidial stage ; while necrotic lesions appeared at the late pycnidial stage and perithecial stage. In the last stage of perithecia formation, necrotic lesions may dry up and become shotholes. Depending on clones a lesion does not have to bear conodia, pycnidia or perithecia (Fig. 1).

Table 4. *Disease development in relation to leaf age*

Leaf age (weeks)	Leaf colour	Stage of disease development
1	Reddish brown	Infection
2 – 4	Olive green	Conidial production
5 – 7	Dark green	Pycnidia formation
> 7	Old dark green	Perithecia formation

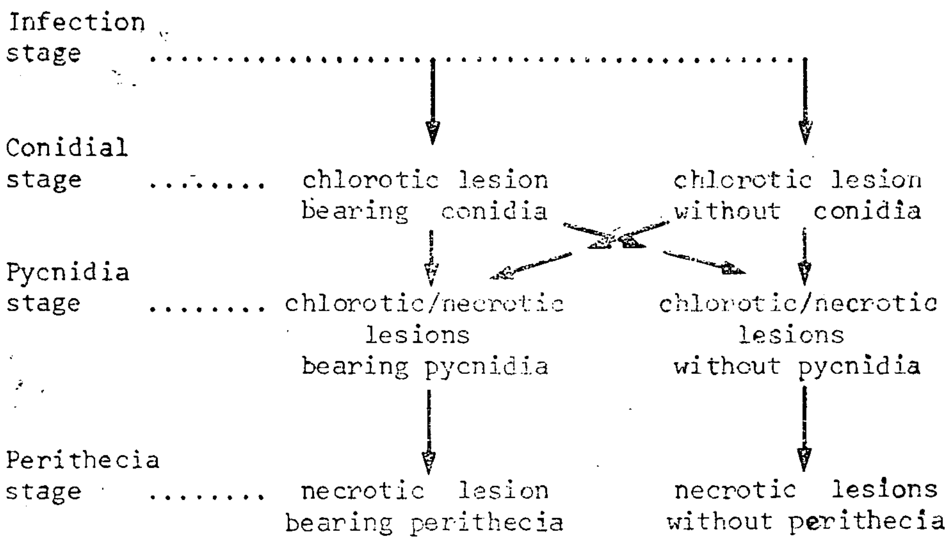


Fig. 1. Stages of disease development on *Hevea* leaves infected by *M. ulei*.

Table 5 shows the differences in sporulation of different clones. Clones having *H. benthamiana* parentage, such as FX 3925, FX 2804 and IAN 717 produce more perithecia than pure *H. brasiliensis* clones. Although *H. benthamiana* confers resistance to the clones but these clones are not necessarily better than *H. brasiliensis*. Of the eight clones in Table 5, FX 985 would be a preferred clone to plant for a disease control, point of view because it produces least conidia and perithecia.

Table 5. *Sporulation of* M. ulei *on different* Hevea *clones*

	Conidial * population	Av. no. of necrotic lesions per cm² with & without perithecia	% of necrotic, lesion bearing perithecia
FX 985	++	5	9
FX 4163	++++	8	9
FX 2261	++	16	11
IAN 873	+++	7	12
FX 3864	++	14	50
FX 3025	++	9	100
FX 2804	++++	17	100
IAN 717	+++	20	100

* Increasing level (+ → ++++)

For the control of South American leaf blight, clones exhibiting the following characteristics should be planted :

* Resistance to the disease in the planting region.

* Infected leaves do not produce much conidia and perithecia of the fungus.

* Rapid refoliation after wintering.

REFERENCES

ANON, (1971). Pesquisas e Experimentacao com a seringueira, Amexo XI. Plano Nacional da Borracha, Ministerio da Industria e do Comercio, Superintendencia da Borracha. Brazil. 108 pp.

CHEE, (1975). South American leaf blight of *Hevea brasiliensis* : Spore behaviour and screening for disease resistance. *International Rubber Conference, Kuala Lumpur, Malaysia.* Reprint, 8 pp.

CHEE, K. H. & T. W. DARMONO, (1984). The occurrence of five races of *Microcyclus ulei* on *Hevea* rubber in Bahia, Brazil. Unpublished information.

DARMONO, T. W. & K. H. CHEE, (1984). Susceptibility of *Hevea* clones to races of *Microcyclus ulei* in Brazil. Unpublished information.

HILTON, R. N. (1955). South American leaf Blight. A review of the literature relating to its depredations in South America, its threat to the Far East and the methods available for its control. *J. Rubb. Res. Inst. Malaya* **14,** 287 - 337.

HOLLIDAY, P. (1970). South American leaf blight (*Microcyclus ulei*) of *Hevea brasiliensis. Phytopath., Paper* No. 12, 31.

LANGDON, K. R. (1965). Relative resistance or susceptibility of several clones of *Hevea brasiliensis* and *H. brasiliensis* × *H. benthamiana* to two races of *Dothidella ulei*. *Pl. Dis. Reptr*, **49** : 12 — 14.

LANGFORD, M. H. (1945). South American leaf blight of *Hevea* rubber trees. *Tech. Bull. U.S. Dep. Agric.* **882**, 31 pp.

LANGFORD, M. H. (1946). Regional differences in resistance of *Hevea* selections to South American leaf blight. *Abs. in Phytopathology*, **36**, 686.

CRITICAL BIO-PHYSICAL ANALYSIS OF THERMAL FOGGING FOR CONTROL OF RUBBER LEAF DISEASES IN BRAZIL[1]

By

J. L. PEREIRA[2], JACKSON DE O. CEZAR[2] & K. H. CHEE[3]

([1]*Divisao de Fitopatologia, CEPEC/CEPLAC, Caixa Postal 7, Itabuna, Bahia, Brazil. Grant CEPLAC/EMBRAPA/ (EMBRAPA/SUDHEVEA)*)
([2]*Div. of Plant Pathology CEPEC/CEPLAC, Bahia, Brazil*)
([3]*RRIM, Malaysia*)

INTRODUCTION

Fungicide applications have been the main method used in the control of *Microcyclus ulei* (P. Henn) V. Arx (Rocha, 1972 and Aitken *et al* 1975). Other important pathogens are *Phytophthora* spp. also requiring fungicide treatment. High technology in systems of application is required to control these foliar diseases of rubber. This is due to the fact that large areas need to be treated within an interval of 1 week, eight or more applications per season in a tree crop of about 20 m in height where access to ground machinery is virtually non-existent. Either aerial spraying with rotary wing aircraft or thermal fogging, in principle, appear to offer a practical solution. However, the availability of helicopters and their high operational costs limit their use. Whereas, thermal fogging, a new technique for disease control, yet needs to be proved effective. The very nature of thermal fogging, unlike other systems, requires investigations in various aspects of operation, in order that fungicide deposits on targets may give the desired effects. In this paper an attempt is made, to demonstrate sequential investigations undertaken in a physical and biological analysis of thermal fogging, accumulating data from previous investigations (Pereira, *et al*, 1980 and Cezar, 1982) and more recent studies. Therefore, it is intended that basic information in each aspect leading to efficient field disease control be critically analysed.

Results of sequential investigations

Mechanical components

Thermal foggers, in their very mechanical design were not intended to operate with wettable powder formulations of fungicides. Insecticides, either concentrated emulsions or solutions are generally used in foggers. The fact that wettable powders need to be used at high concentrations, resulted in problems in the hydraulic circuit, mainly due to abrasive action in the pump and crust formation in the product injector, interrupting flows. The problems with the pump were resolved having been replaced by piston pumps following investigations by a SUDHEVEA technical assistance team. Therefore, investigations were concentrated on the burner component with the object of, (a) reducing crust formation on the outlet tube ; (b) more effective burning with minimum duration of product in contact with the heated surface ; (c) economic use of fuel (gas) ; (d) better utilization of the air blast. Two designs were developed. In the first design (Fig. 1) the contact

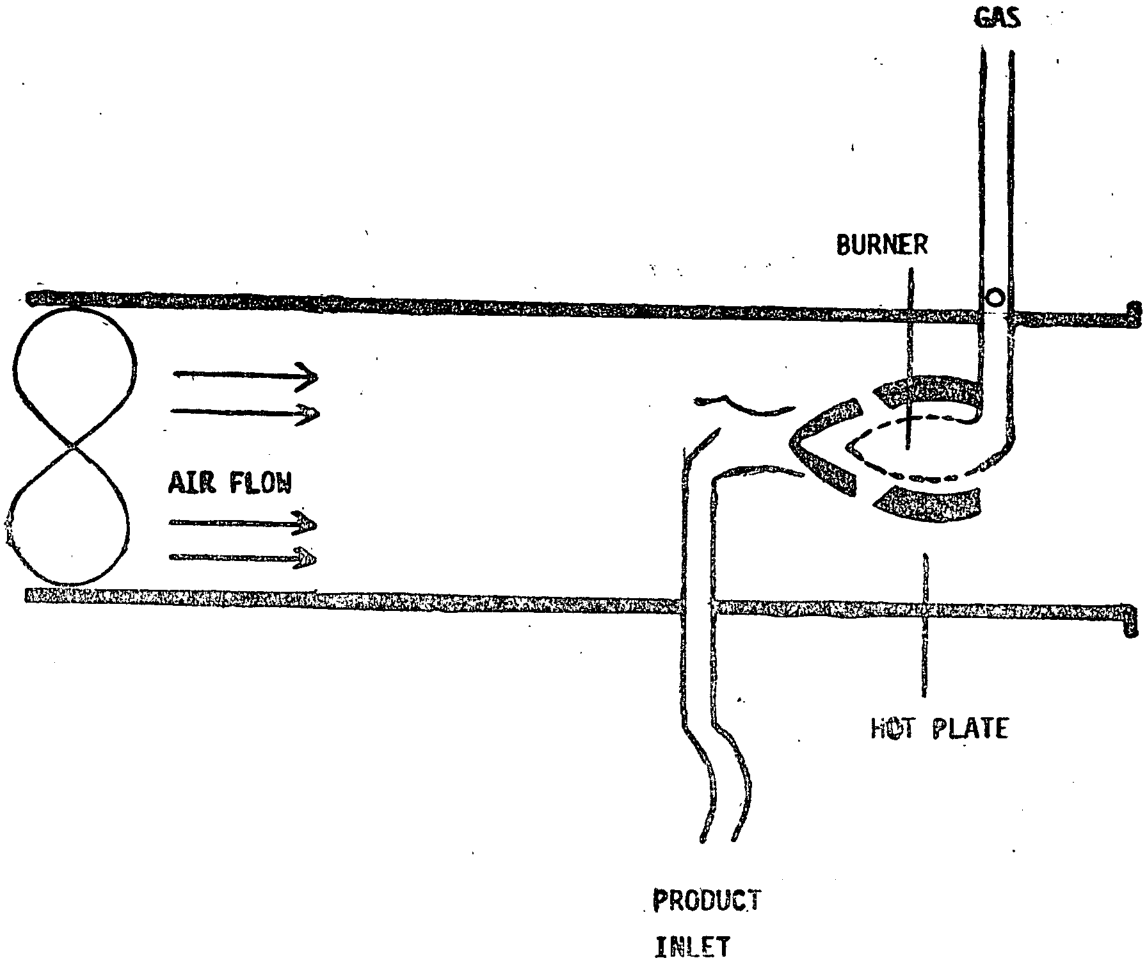


Fig. 1. Suggestion for a Thermal Fogger Burner.

of the product with the heated surface was reduced to a minimum in terms of duration in time. This would occur due to impact of the product onto a conical configuration where immediately liquid is transformed into gas, the gas feeds into the air stream. Again since the inlet tube is not exposed to heat, crust formation is not expected to build up, in addition, the final part of the flow is by twin fluid action that is, air/liquid spray. The second design was more ambitious (Fig. 2) where the burner was separated from the main air flow. In this way the full potential of the air blast may be utilized. Also, since the burner is separated from the main airflow, the gas consumed would be less, at the same time allowing for ease in clearing operations.

Formulations and diluents

A series of combinations were made with the commonly used fungicides (Mancozeb, Benomyl, Thiophanate methyl and coppers), emulsifying agents, oil and water to obtain stable emulsions. The best combination (Table 1) consisted of stock emulsions to be used without diluting for fogging or with 3 parts of water for aerial spraying.

Table 1. *Suggestions for preparing litre stock of emulsions of five different fungicides for the control of rubber diseases*

Component	Benomyl	Thiophanate Methyl	Mancozeb	Copper Oxichloride	Cuprous Oxide
Fungicide (product) (g)	60	80	300	400	400
Water (ml)	90	90	300	250	250
Triton X — 114 or Triton X — 45 (ml)	10	10	10	10	10
Spray oil (ml)	880	880	550	500	500

RE : The stock emulsions are diluted in the ratio of 1 : 3 (stock : water) for aerial spraying and undiluted in fogging.

Oil diluents play an important role in fog generation in respect to ease of flow (viscosity), the temperature point or vapour formation and calorific values of the diluents or energy requirements for their transformation. In Table 2, a comparison between national and imported spray oils suggest that the national spray oil may be inadequate for use in thermal foggers due to undefined point at which vapour is produced. It is suggested that this oil may constitute a mixture of fractions each with different boiling point temperatures. On the other hand, vegetable oils like palm oil are good substitutes for mineral oil, however, requiring higher temperatures for fog generation and higher fuel consumption.

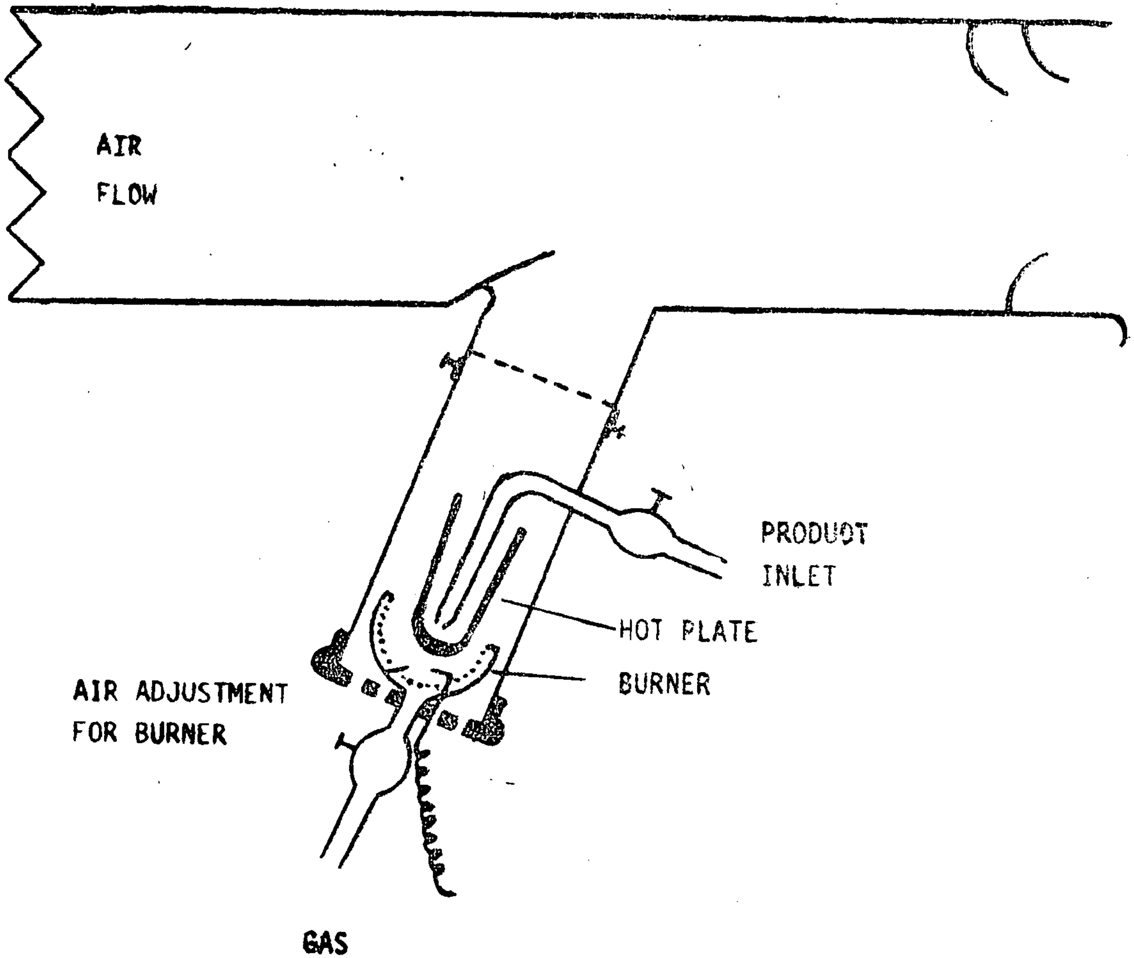


Fig. 2. Suggestion for a Thermal Fogger Burner

Table 2. *Physical characteristics of some diluent oils utilized in thermal fogging*

Diluent	Flow rate ml/min	Specific weight g/ml	Vapour point °C	Ebullition point °C	Time for ebullition min/600 ml
Water	107,15	0,99	99	101	15'00"
National spray oil	21,58	0,84	**	**	**
Imported spray oil	15,87	1,12	138	153	17'30"
Palm oil	11,77	0,90	94	197	22'30"
Diesel	58,83	0,84	87	189	21'24"
Natural oil	13,96	0,90	87	166	20'00"

* Standard
**No ebullition after 1 hour 45 minutes, at 250°C temperature.

Certain difficulties are encountered when formulations have to be made in oil/water mixtures. Firstly, in the hydraulic circuit of spraying equipment a force is exerted on the spray liquid in the pump and channelled through tubes often at acute angles, this, when simulated in the laboratory, suggested a differential separation, possibly influenced by specific gravity, viscosity and density values. In this case the results show that a greater part of the fungicide remains in the water phase (Table 3). However, this may not be the case when separation is due to sedimentation. Based on these results, the use of water in a thermal fogging oil formulation should be avoided. Even further, there exists a risk of poor adhesive properties of the fungicide deposit on young rubber leaves when an oil/water mixture is used (Table 4).

Table 3. *Percentage inhibition of " in vitro " germination of* M. Ulei *by water and oil/water formulations of Benomyl*

1. **Centrifuged**

Inhibition in relation to control		Fungicide prepared in: Water	Oil/Water	
		Water phase	Water phase	Oil phase
Water		70	68	42
Emulsion without fungicide	Water phase	65	64	34
	Oil phase	68	67	39

2. **Sedimented during 24 hours**

Inhibition in relation to control		Fungicide prepared in: Water	Oil/Water	
		Water phase	Water phase	Oil phase
Water		80	85	81
Emulsion without fungicide	Water phase	78	79	83
	Oil phase	80	85	81

Table 4. *Inhibition zones of* Penicillium *Sp. resulting from two Benomyl preparations sprayed on rubber leaves*

Fungicide preparation	New leaves		Old leaves	
	Without rain	With rain**	Without rain	With rain**
Oil/Water	87,9	0	88,8	70,8
Water	93,5	74,8	92,9	81,0
Control*	0	0	0	0

Re : * Unsprayed leaves were used for control
** 7 mm of rain in 30 hours

Thermal effects on fungicides

Two experiments were undertaken to determine if high temperatures in thermal fogging results in degradation of fungicides. The commonly used fungicides applied with a thermal fogger, captured 1 m from the delivery tube did not degrade, suggesting that the fungicides exposed to heat for a fraction of a second do not influence properties of the products (Table 5). However, under laboratory conditions when fungicides are subject to heat for a duration of 1 minute, as temperature levels are increased, the products undergo degradation (Table 6).

Table 5. *Percentage inhibition of " in vitro " germination of conidia of* M. Ulei *influenced by formulations sampled before and after fogging*

Fungicide preparations	P.P.M. 10		100		1000	
	Fogging					
	Before	After	Before	After	Before	After
Thiophenate Methyl (Cercobin)	16	14	92	88	100	100
Benomyl (Benlate)	62	63	80	83	97	100
Mancozeb (Dithane M — 45)	64	52	100	100	100	100
Cuprous Oxide (Cobre Sandoz)	4	8	46	82	93	99
Diesel	7	0	12	7	15	15

Control = 0% Inhibition

Table 6. *Percentage "in vitro" germination of conidia of* M. ulei, *influenced by fungicides exposed to three temperature regimes of 1 minute duration*

Fungicides	Untreated (P.P.M.)			200°C (P.P.M.)			400°C (P.P.M.)			600°C (P.P.M.)		
	1	10	100	1	10	100	1	10	100	1	10	100
Mancozeb (Dithane M - 45)	32	39	91	12	18	76	4	5	30	7	17	28
Thiophenate Methyl (Cercobin)	20	34	42	8	10	22	1	1	13	1	1	1
Benomyl (Benlate)	49	51	66	1	3	3	12	10	12	6	10	11

Control = 0% Inhibition

Droplet distribution studies

In an adult rubber plantation vertical and horizontal swath determinations were made on artificial targets. Three thermal foggers were tested at varying angles of delivery, and under different ambient conditions. The Tifa, delivering at 45° resulted in less loss to the ground and a more uniform distribution pattern, compared to horizontal or vertical delivery settings. Droplet densities of over 50 droplets/(per cut) cm² were captured up to 140 m and 10 m in height. However the height value may be projected to 16 m (Chee, 1976). In all cases, the mean for three applications were made, yet all with high coefficient of variation values. In the case of the Leco and Jacto machines, where the object was to determine ideal ambient conditions for application, inconsistency in distribution patterns became very apparent. It was clear that neither low (less than 3·6 km/h) nor high (over 5·8 km/h) wind speeds favour applications (Figs. 3 — 14). Little difference exists between the imported Leco and the nationally manufactured Jacto, however, Jacto offers various advantages in ease of operation.

Phytotoxic effect of oil diluents

Spray oils, as diluents, were tested for characteristics appropriate for use in thermal foggers (Table 2). These products, spray oil (imported, Shell spray oil No. 3), Petrobras spray oil (National), palm oil and natural oil (soya bean oil and emulsifier) were also tested for phytotoxic effects on rubber seedlings. Plastic tents were placed over rubber seedlings and predetermined quantities of fog were injected into the closed ambient. After 10 minutes the tents were removed and the seedlings examined at various hourly intervals for phytotoxicity. All oils had no adverse effect on the seedlings, however, after a period of 3 months a variation in growth rate was observed between seedlings of different treatments (Table 7). The higher the concentration of the diluents, the more severe the effects on growth of the seedling, and even more important, the vegetable oils were less phytotoxic.

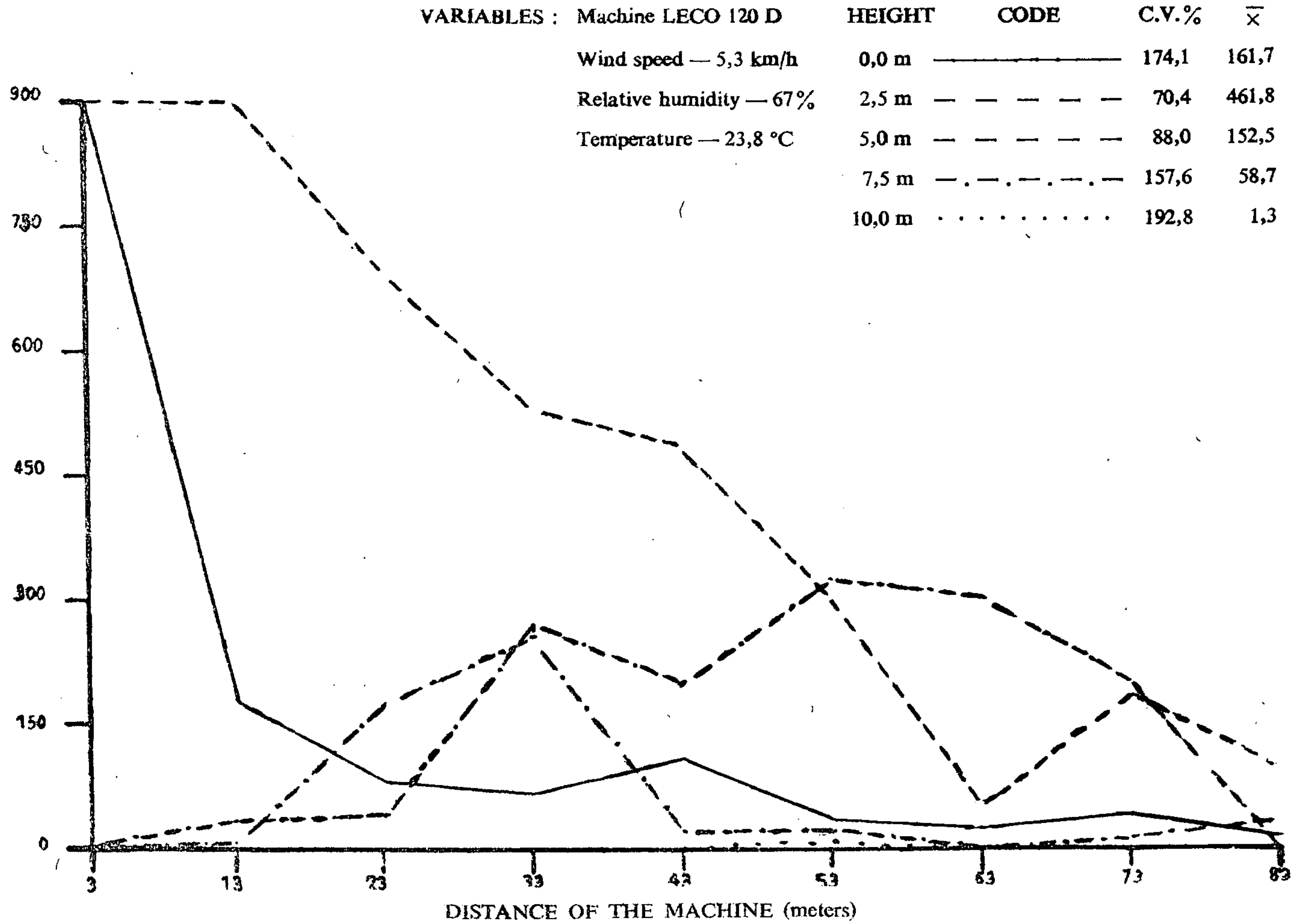


Fig. 3. Droplet distribution on horizontal and vertical swath in adult rubber.

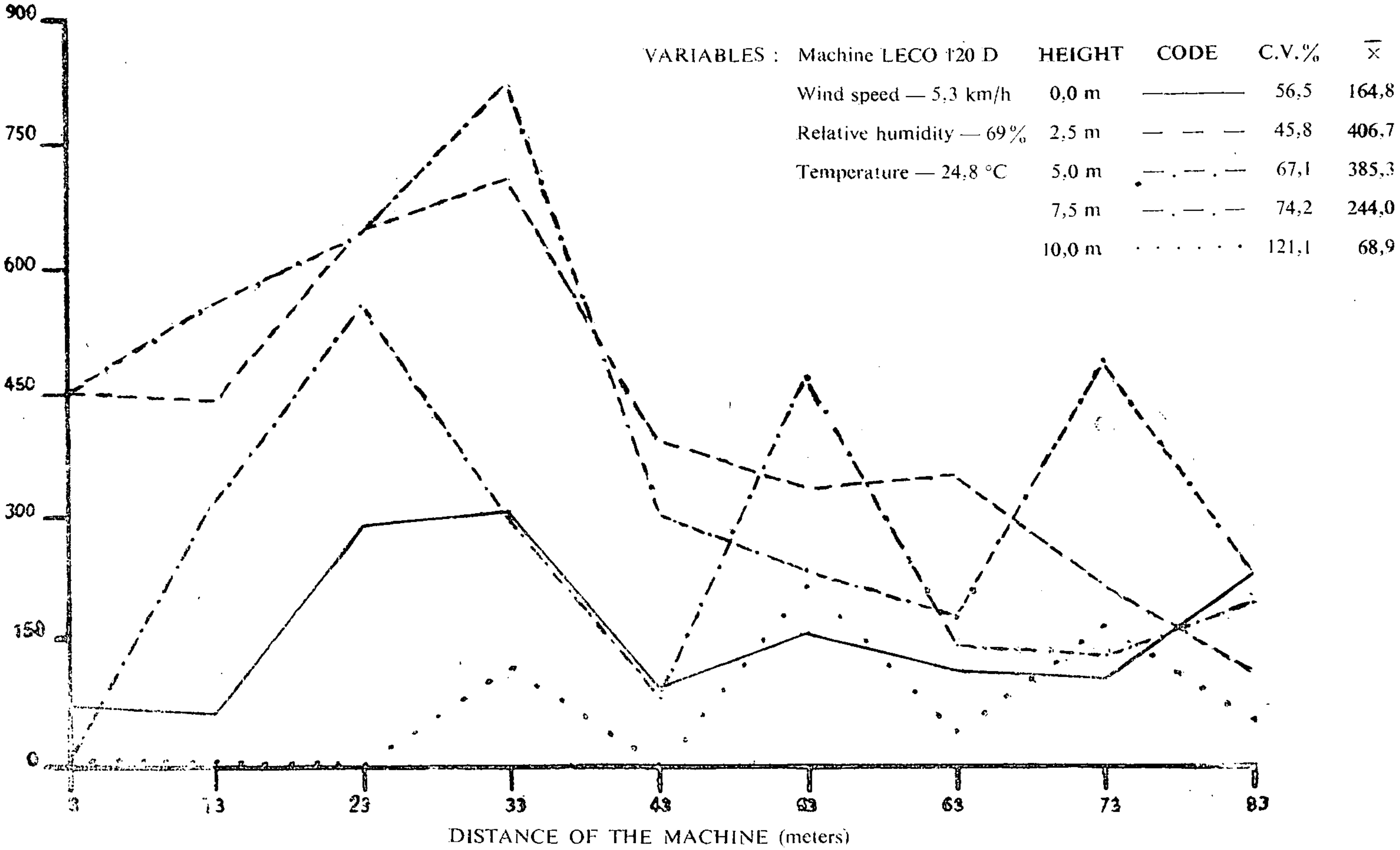


Fig. 4. Droplet distribution on horizontal and vertical swath in adult rubber.

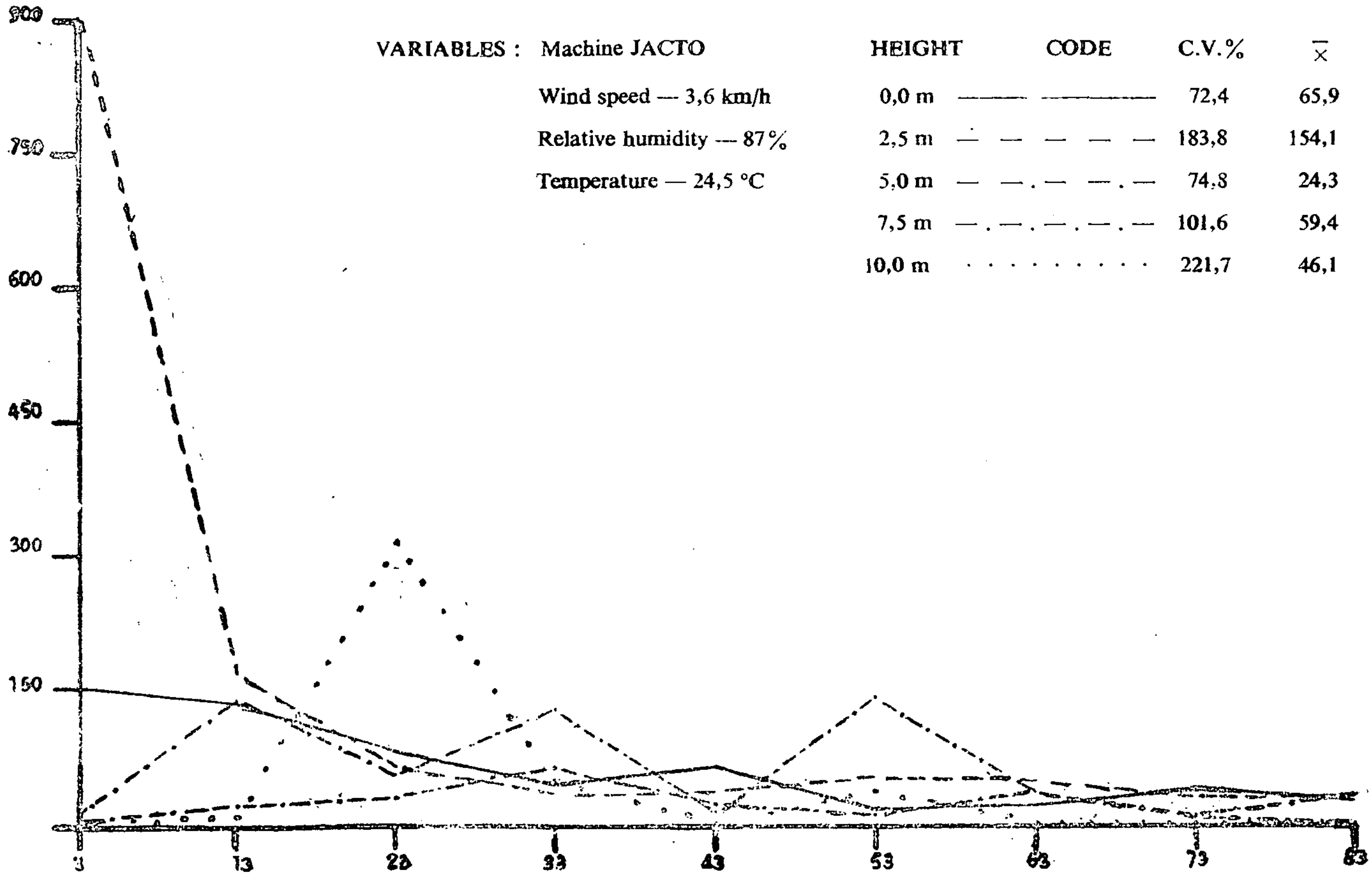


Fig. 5. Droplet distribution on horizontal and vertical swath in adult rubber.

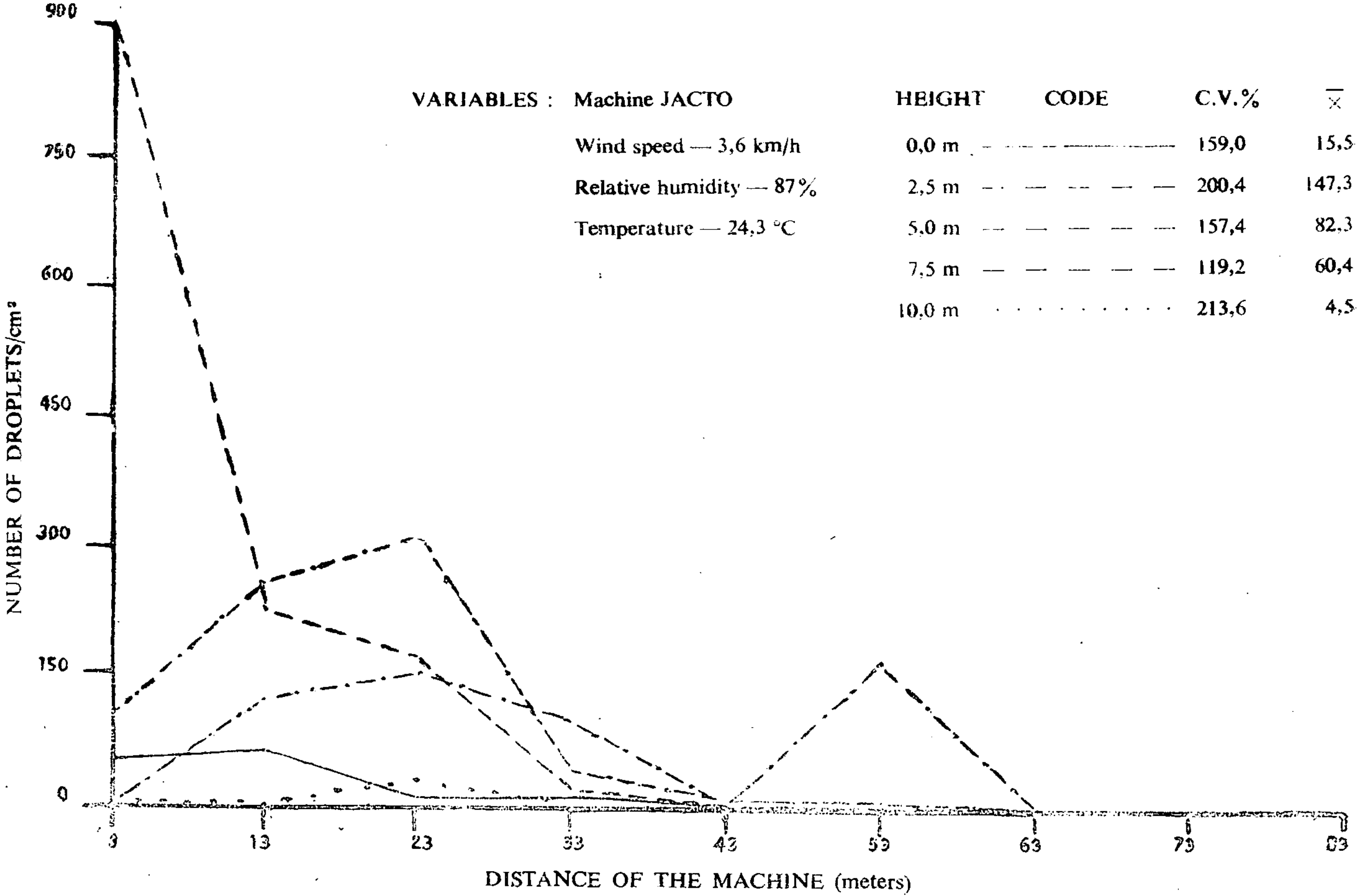


Fig. 6. Droplet distribution on horizontal and vertical swath in adult rubber.

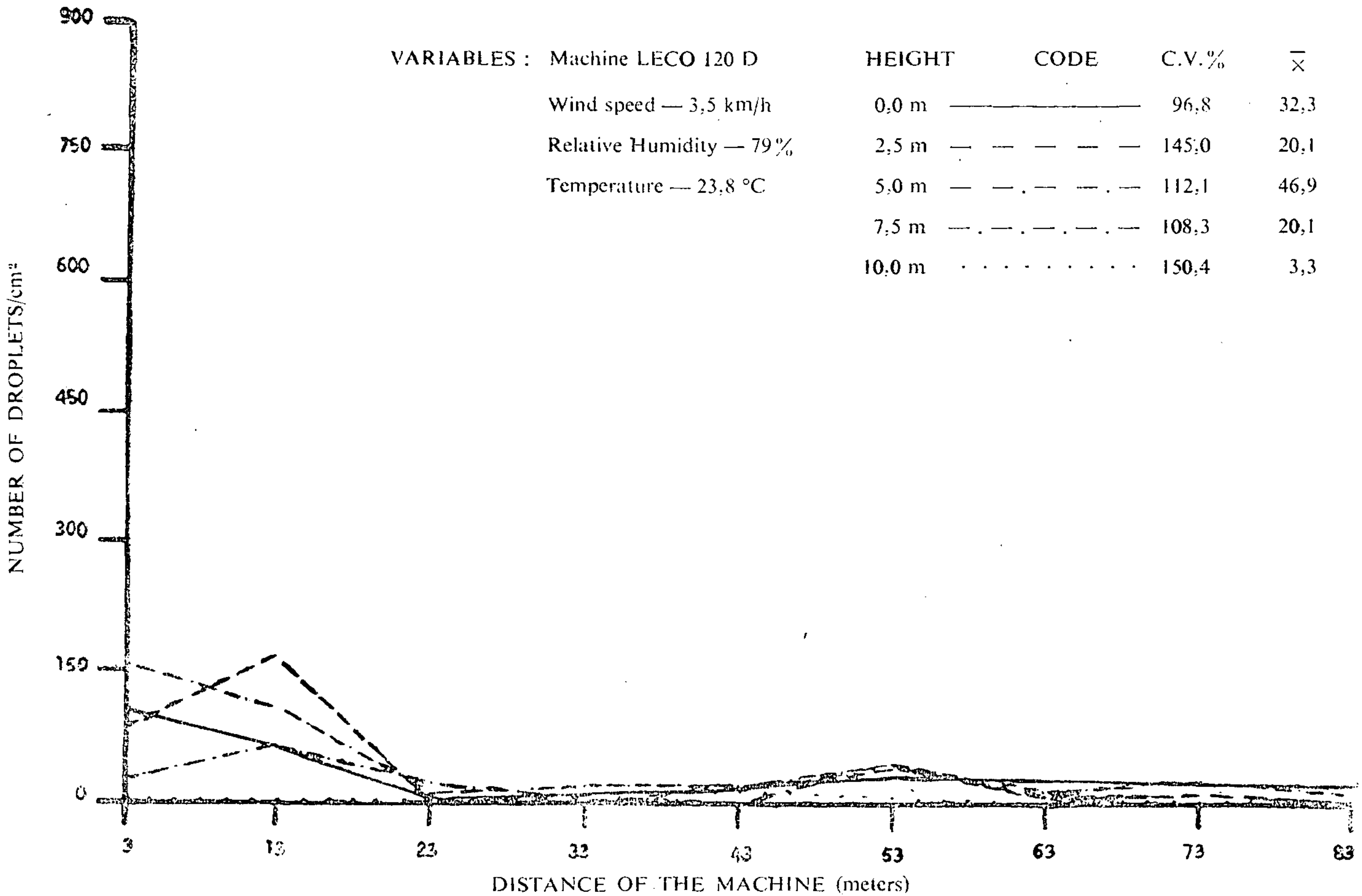


Fig. 7. Droplet distribution on horizontal and vertical swath in adult rubber.

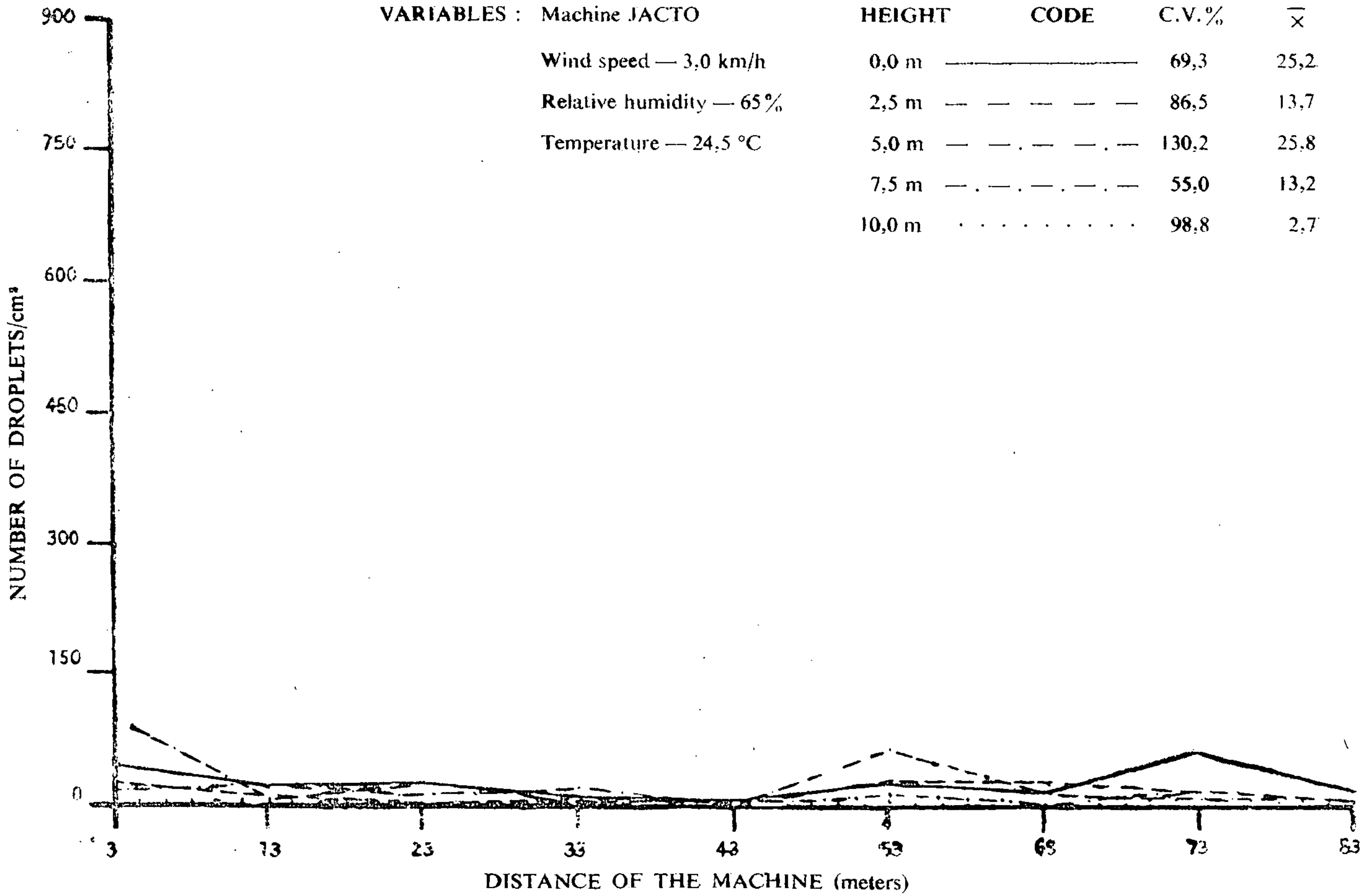


Fig. 8. Droplet distribution on horizontal and vertical swath in adult rubber.

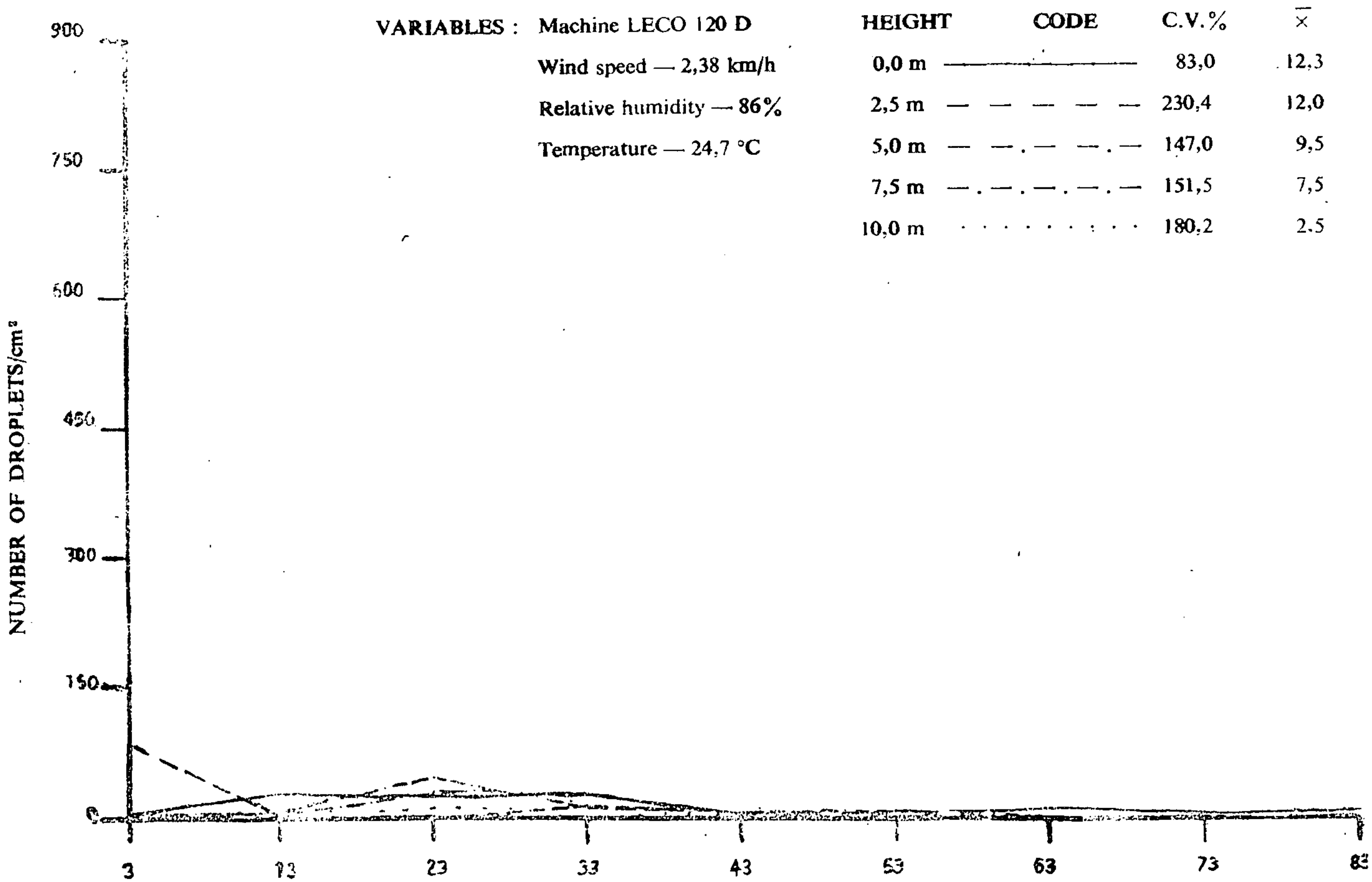


Fig. 9. Droplet distribution on horizontal and vertical swath in adult rubber.

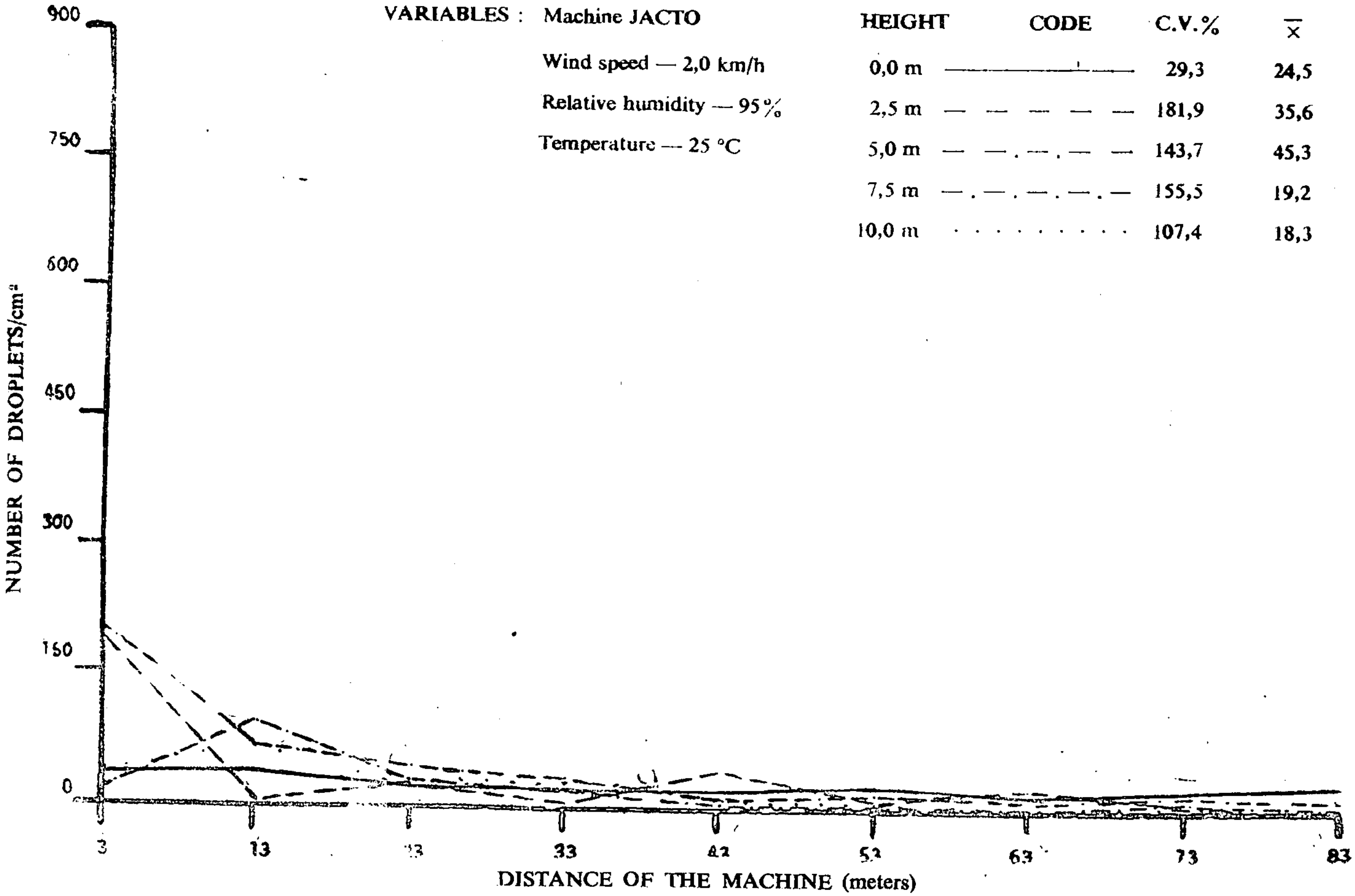


Fig. 10. Droplet distribution on horizontal and vertical swath in adult rubber.

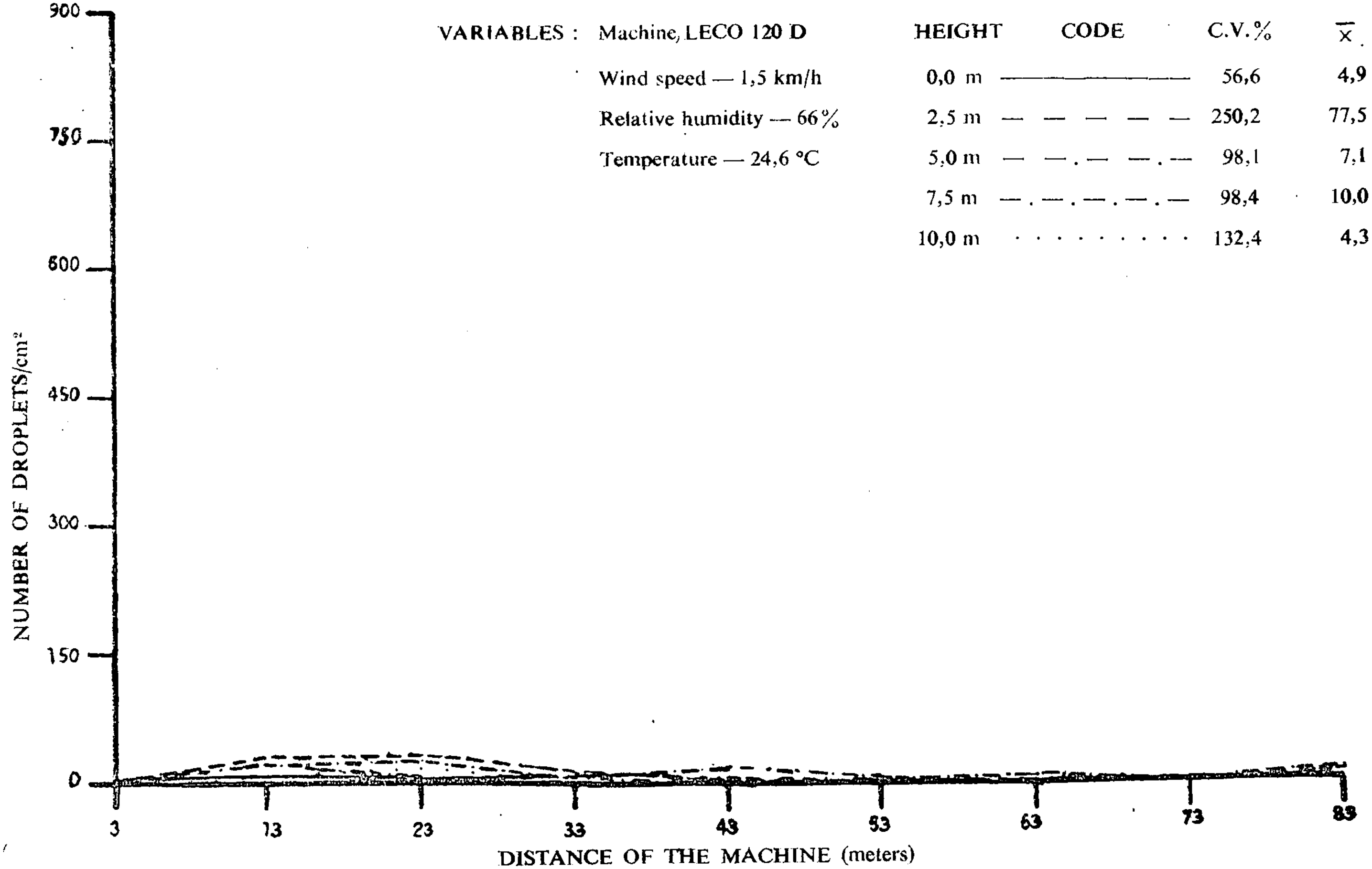


Fig. 11. Droplet distribution on horizontal and vertical swath in adult rubber.

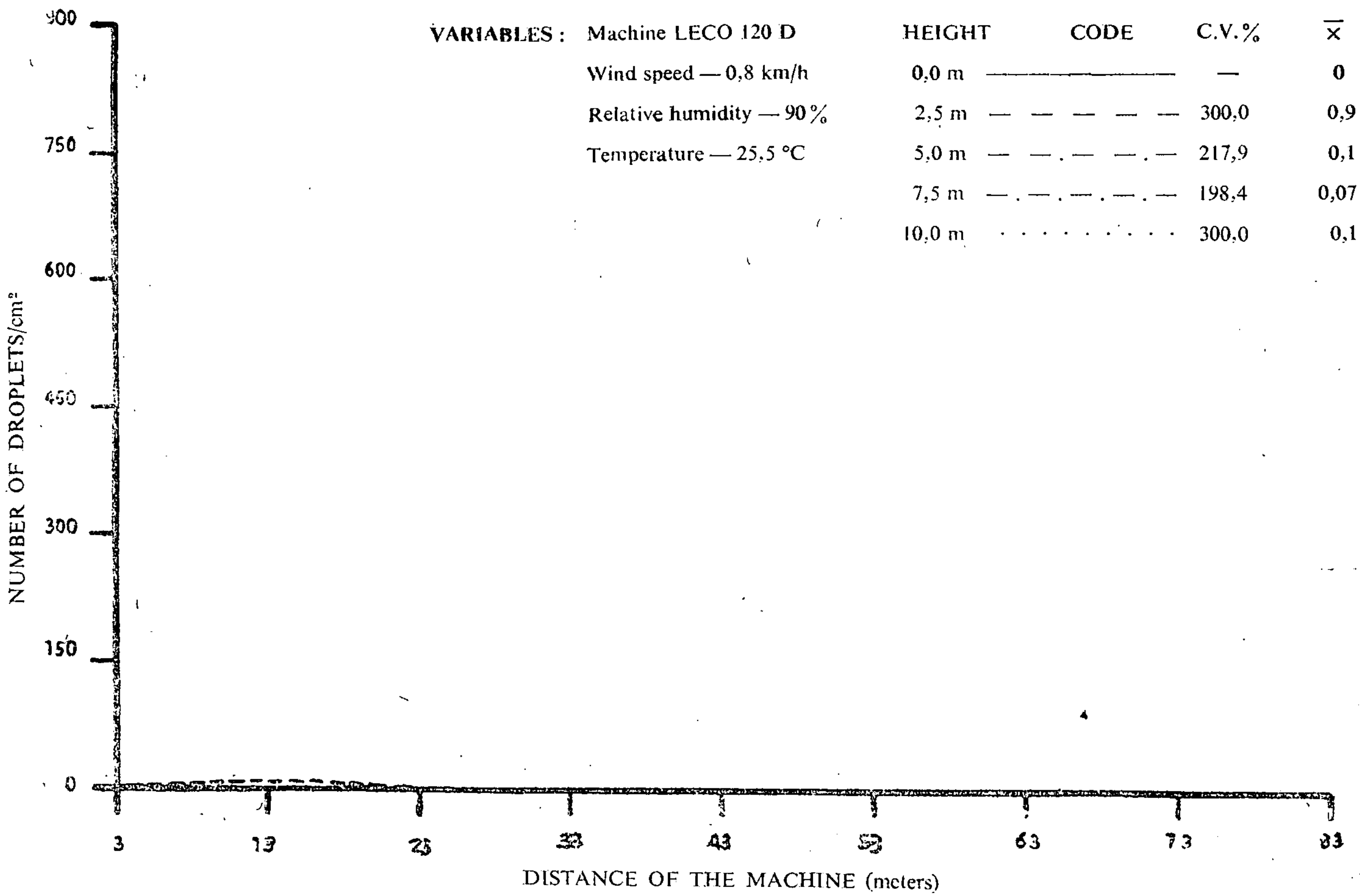


Fig. 12. Droplet distribution on horizontal and vertical swath in adult rubber.

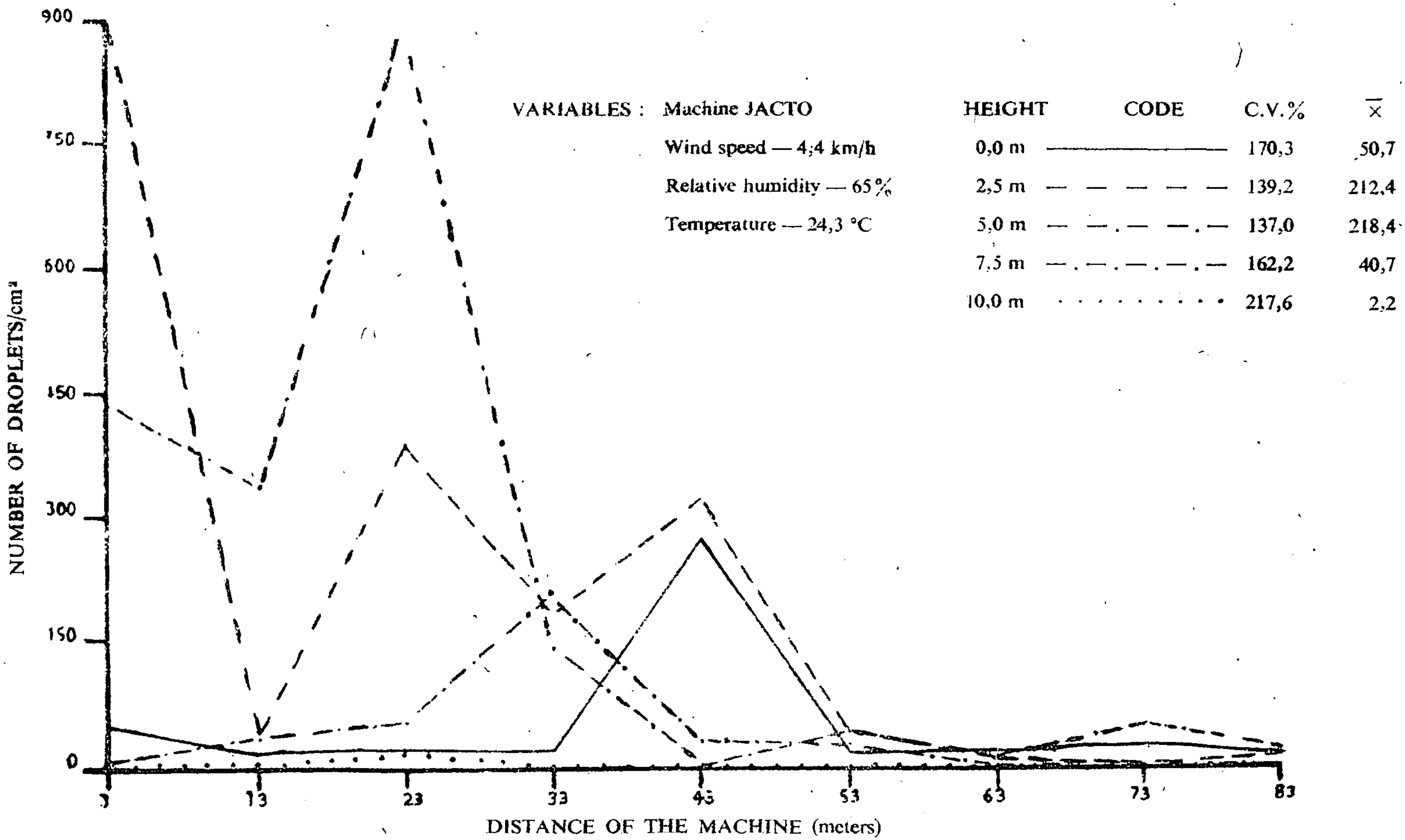


Fig. 13. Droplet distribution on horizontal and vertical swath in adult rubber.

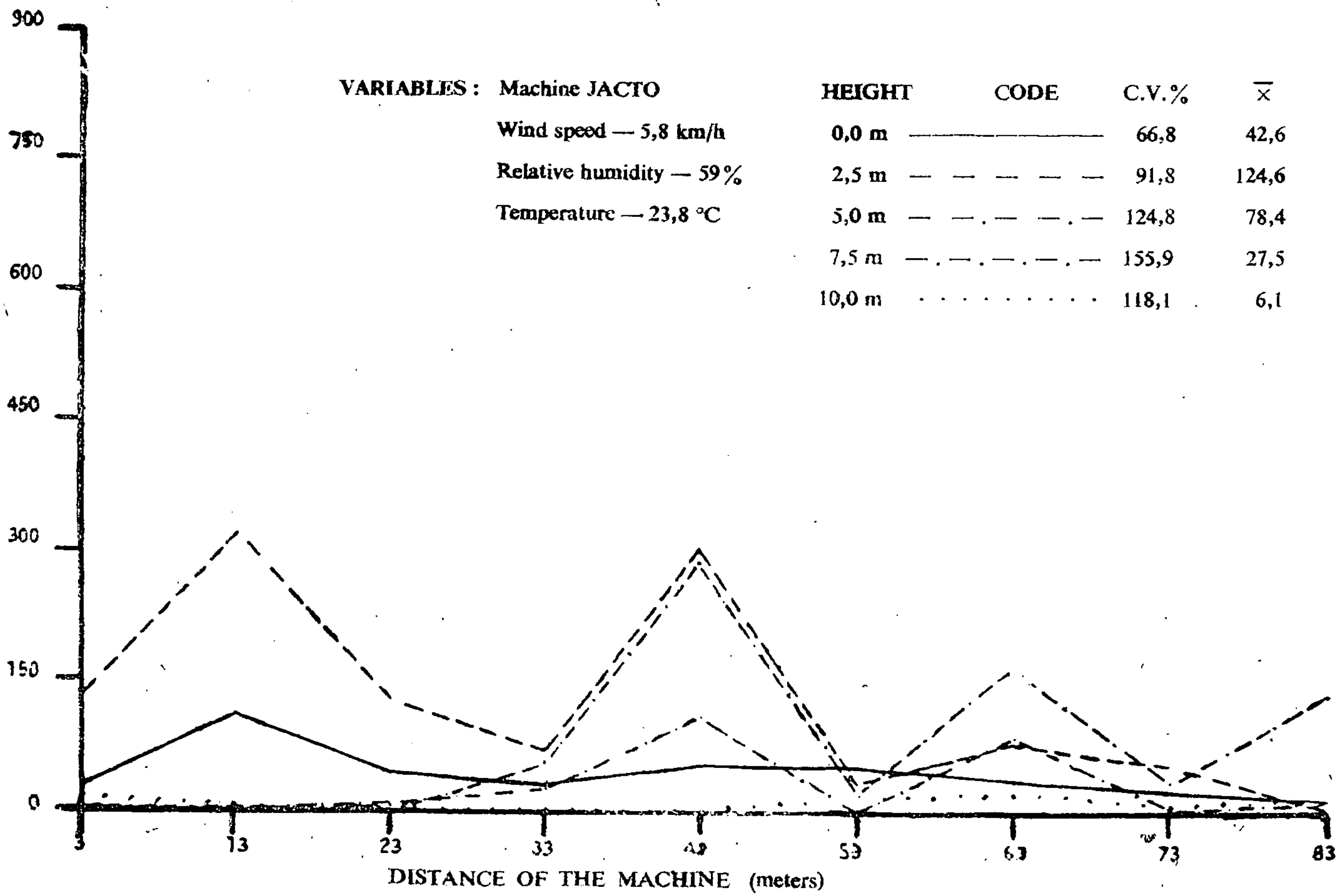


Fig. 14. Droplet distribution on horizontal and vertical swath in adult rubber.

Table 7. *Phytotoxic effect of diluent oils on the growth of rubber seedlings (90 days after fogging)*

Treatments*	Height of seedlings cm	Number of leaves	Green weight	Dry weight
Diesel 5,7 ml/m³	103,92	15,3	199,69	90,13
Diesel 20 ml/m³	73,17	12,1	122,23	42,36
Spray oil 6 ml/m³	79,50	10,4	119,91	43,53
Spray oil 20 ml/m³	74,92	13,3	128,19	45,33
Natural oil 3,9 ml/m³	106,09	15,2	193,19	72,49
Natural oil 15,6 ml/m³	97,34	14,4	215,79	90,02
Palm oil 3 ml/m³	86,13	16,8	259,89	106,45
Palm oil 12 ml/m³	91,00	15,8	271,19	90,95

* Average of 12 seedlings.

Bio-assays of fungicide deposits

One of the causes of the inconsistency of thermal fogging was suspected to be the low concentrations of fungicides used. The recommended dosages per hectare for Benomyl is 150 g ; Chlorothalonil, 1200 g; Mancozeb, 1600 g and Triadimefon, 75 g (Anon, 1983). In the present study, different concentrations of Benomyl, Chlorothalonil and Triflorine were fogged and the treated leaves were bioassayed. Triflorine was tested because it has shown promise in controlling SALB in the nursery (Dos Santos *et al*, 1984) and being an emulsified concentrate, it is most suited for fogging purposes.

The experiments were carried out at the CEPLAC/EMBRAPA Experiment Station (EDJAB) in Una, Bahia. The experimental plot was 1·5 hectares of mature rubber planted on a flat terrain. The thermal fogger used was a Brazilian made Jacto 1 and less frequently a US made Leco 120. The fogger temperature was adjusted as 600°C and the fog emission rate 3.5l/min. The fogger was trailed by a tractor with a forward speed of 50 m/min. The time of fogging and the prevailing wind speed were recorded for each experiment.

At the time of the experiment, there was no young foliar shoots on trees. Instead, young shoots of FX 3864 or FX 4163, each having 10 to 20 young leaves (approximately 7-day-old) were cut from a nearby nursery and raised by a nylon thread to heights of 5 and sometimes 10 m as well, in the canopy. Soon after fogging the shoots were lowered and the leaves cut and placed in polythene bags for transport back to the laboratory.

Table 8. *Summary of* Hevea *leaves using* Microcyclus ulei *as bioassay organism after fogging*

Expt. No.		1 — 1	1 — 2	2 — 1	5 — 3	4 — 1	4 — 2	5 — 2	6 — 1	7 — 2	3 — 3	5 — 1	6 — 2	7 — 1	3 — 1	4 — 3	3 — 2	4 — 4	4 — 5
				Benomyl											Triforine			Chlorothalonil	
Fungicide g/ha.		100	100	350	350	500	500	500	500	500	1000	1000	1500	190 ml	380 ml	380 ml	750	750	750
Time application		1830	0530	0600	1030	1530	1700	2030	1700	1800	0600	1930	1830	1715	0645	1730	0745	1945	0550
Wind speed km/ha.		0	0	0	2·3	4·8	1·6	0	3·9	0	0	0	0	4·29	0	0	0	0	0
Distance from fogger (m)	Tree height																		
10	5 / 10	— / —	— / —	D	+	—	—	D	+ / —	— / +	—	+	NT / +	— / —	—	—	—	—	+
20	5 / 10	+ / —	— / —	—	—	—	—	D	NT / —	— / —	+	D	+ / +	— / —	—	—	+	—	—
30	5 / 10	— / —	— / —	D	—	—	—	+	— / —	— / —	+	D	NT / +	— / +	+	—	—	—	+
40	5 / 10	— / —	— / —	D	—	—	—	—	+ / —	— / +	+	D	+ / —	+ / —	—	—	—	—	—
50	5 / 10	— / —	— / —	—	+	—	—	D	NT / —	— / —	—	D	— / +	— / —	—	—	+	—	—
60	5 / 10	— / —	— / —	—	—	—	—	D	+ / +	+ / —	—	—	— / +	+ / —	—	—	—	—	—
70	5 / 10	— / —	— / —	D	—	—	—	D	+ / —	— / —	—	+	— / —	— / —	+	—	+	—	—
80	5 / 10	+ / —	— / —	—	—	—	—	D	+ / —	+ / +	—	+	— / NT	— / —	—	—	D	—	—
90	5 / 10	— / —	— / —	D	—	—	—	+	— / —	+ / —	—	+	— / +	— / —	—	—	—	—	+

D, Leaf discs decayed ; NT, Not tested ; (+) and (—), Reduction of lesion number more than or less than 50% respectively.
Seven litres of spray oil per hectare were used, except Expt. 1 — 1, 1 — 2 and 2 — 1 where palm oil was used.
The fogger used was that of Jacto, except Expt. 2 — 1 where Leco 120 was used. Tractcr running speed, 50 m/min ;
Fogger temperature, 600°C ; Topography of experimental plot, flat ; Fog emission rate, 3,5 1/min.

Two methods were used to assay the leaves microbiologically. In the first method, eight leaf discs 15 mm diameter were cut from each shoot and four were placed on a PDA plate with the adaxial surface uppermost. The plates were sprayed with the spores of the assay organism *Penicillium* sp. The zones of inhibition around the leaf discs were measured after 48 hours.

In the second method, 10 leaf discs were floated on water in Petri dishes with the abaxial leaf surface uppermost (Chee, 1976). The leaf discs were sprayed with a conidial suspension of *M. ulei*, race 3. The number of lesions on leaf discs were counted after 7 days incubation under light (2600 lux at 24°C).

The *Penicillium* method of bioassay was found to be far less sensitive to the *Microcyclus* method. Therefore, Table 8 presents results only with the latter method of bioassay. A positive (+) result was when the percentage lesion reduction of the treated leaf discs as compared to the untreated control was greater than 50%, and negative (–) when less than 50%. The results show that fogging with higher fungicide concentrations, but not low concentrations, does give fungicide deposition to the abaxial leaf surface for protection against SALB. But the results were not consistent, even with Benomyl at 500 g/ha or Chlorothalonil at 700 g/ha. The importance of protecting the abaxial leaf surface is because spore infection is likely to occur mostly on the abaxial leaf surface on which subsequent lesion development takes place. Fogging in a still atmosphere or at a wind speed up to 2, 3 km/h gave almost the same poor result.

CONCLUSIONS

Results of a sequential investigation on various aspects of thermal fogging such as mechanical components, formulation and diluents, thermal effects on fungicides, droplet distribution studies, phytotoxic effects of oil diluents, suggest that present knowledge permits improvements in the possibility of fogging in certain aspects.

Mechanical components and the unit as a whole may be greatly improved, including the possibility of crust formation at the emitting point to avoid a variation in flow rates. Mineral oil diluents may be substituted for readily available and often less costly vegetable oils, although higher calorific values are necessary for comparative volumes, and viscosity differences have to be adjusted in flow rates, permitting a precise dose application.

Finally, in terms of actual quantity of fungicide that deposits on the targets (young leaves) the bio-assays suggest that the doses do not attain the desired lethal effect to offer an acceptable degree of control of *M. ulei*.

REFERENCES

ANON, (1983). Sistema de producao de seringueira para a regiao Sul da Bahia. CEPLAC/EMBRAPA/SUDHEVEA/EMBRAPA, 48 pp.

CHEE, K. H. (1976). Assessing susceptibility of *Hevea to Microcyclus ulei*. *Ann. Appl. Biol.* **84**, 135 — 145.

DOS SANTOS, A. F., PEREIRA, J. C. R. AND ALMEIDA, L. C. C. (1984). Control equimi co do mal-das-folhas (*Microcyclus ulei*) da seringueira (*Hevea* sp.). Resumos dos Trabalhos, Seminario Nacional da Seringueira, Salvador, BA., 10 — 16 de junho, 1984.

PEREIRA, J. L., RAO, B. S. AND RIBEIRO, J. O. (1980). Papel do oleo nas formulacoes de fungicidas no controle de *Microcyclus ulei.* III Seminario Nacional da Seringueira e Simposio Internacional sobre Borracha, Manaus, AM., 23 — 29 de junho de 1980.

CEZAR, J. DE O. (1982). Termonebulizacao em seringueira — Captu ra de gotas e determinacao de faixas. XII Congresso Brasileiro de Engenharia Agricola. CEPLAC/CEPEC, Ilheus, Itabuna, BA., 19 — 23 de julho de 1982.

ROCHA, H. M. (1972). Problema de enfermidades nos seringais da Bahia. *In* : Sem, nario Nacional da Seringueira, 10, Cuiaba, Mato Grosso, 1972. Anais Cuiabai Superintendencia da Borracha, 1972, pp. 99 — 110.

AITKEN, W. M. AND VASCONCELOS, A. P. (1975). Controle do mal-dasfolhas (*Microcyclus ulei*) da Seringueira na Bahia. 1. Pulverizacao com fungicidas na regiao de Itubera. *Revista Theobroma* (Brasil) **5**, 3 — 11, 1975.

ORGANOGRAPHIC VARIABILITY OF STOMATAL CHARACTERS IN *HEVEA BRASILIENSIS* MUELL. ARG. AND ITS POSSIBLE SIGNIFICANCE IN CLONAL SUSCEPTIBILITY TO LEAF FALL DISEASE.

By

D. PREMAKUMARI AND A. O. N. PANIKKAR
(Rubber Research Institute of India, Kottayam 686009 South India)

ABSTRACT

Density of stomata on leaf blade and petiole as well as the aperture size of the stomata on petiole, leaf blade, vein and fruit wall have been studied in six clones of Hevea brasiliensis *of which three were susceptible and the other three were somewhat tolerant to abnormal leaf fall disease. The study revealed that a few stomata are present on the epidermis of petioles, veins, and fruit wall but the stomatal density is very low compared to that in the veinless portion of the leaf blade. The aperture length and aperture width of petiolar and veinal stomata were significantly high compared to those of the stomata on the leaf blade. There was a significant positive correlation between the aperture length of petiolar stomata and that of veinal stomata. The aperture length of fruit wall stomata was comparable to that of petiolar stomata, but was more wide open. It appeared that the organographic variability of stomatal characters have an influence on the organographic specificity of leaf fall disease infection. It also appeared that the aperture index of petiolar stomata was in someway related to the clonal susceptibility to abnormal leaf fall disease.*

INTRODUCTION

A review of stomatal studies in different species reveal a range of structural, functional or ontogenetic variations of the stomata of the leaf laminae. The nature and density of stomata in *Hevea brasiliensis* have also been studied (Bobilioff, 1923 ; Chen *et al.*, 1981 ; Panikkar, 1974 ; Senanayake *et al.*, 1970). Attempts to study the entire stomatiferous area of a plant, however, are very rare. Nevertheless such investigations will yield useful information on the nature and extent of variation of the stomata of the different stomatiferous parts as well as their functional significance. This piece of investigation has been attempted with a view to ascertaining the nature of the stomata on the leaf blade, vein, petiole and fruit wall of *Hevea brasiliensis* and also their probable significance in relation to abnormal leaf fall disease.

MATERIALS AND METHODS

The studies were conducted on six clones of *Hevea brasiliensis* namely, RRII 101, RRII 102, RRII 105, RRII 106, PR 107 and Tjir 1, planted in 1966 in a single tree single plot clone trial with forty replications. Three trees were selected randomly from each clone. Three leaves at random positions on the tree were collected from each. All the leaves collected belonged to comparable nodal positions on the twig. Fruits were collected as available. The sample collections were made when the trees were 15 years of age. Leaf bits were taken out from the middle portion of the central leaflets and peelings of the lower epidermis were prepared. Samples of the petioles were taken 2 cm away from the node and epidermal peelings of the abaxial half were taken. Epidermal peelings of the fruits were also taken. Standard methodology (Purvis *et. al.*, 1966) was followed for the preparation of the peelings and for the staining.

Density of stomata per 1 mm² of the leaf blade and fruit wall and 10 mm² of the petiole was assessed. Length and width of the stomatal aperture were also measured. The aperture index of leaf blade and petiolar stomata have been worked out for which density per 1 mm² was used in both cases. The data were statistically analysed, except for the stomata on the fruit wall.

Field observations were made on the clonal response to abnormal leaf fall disease under normal prophylactic conditions during 3 years.

RESULTS AND DISCUSSION

Stomata were present on the petiole, vein and fruit wall although their number was very low compared to that on the leaf blade. The stomatal density in the petiole and leaf blade in different clones under study are given in Table 1. In the leaf blade, stomatal density varied from 297·0 to 348·3 in an area of 1 mm². The range of stomatal density in *Hevea brasiliensis* as reported by Senanayake *et al.*, (1970) on the leaf blade is comparable to this observation. In the petiole the range was only 3.00 to 5.25 in 10 mm².

Table 1. *Clonal differences in the density of leaf blade and petiolar stomata*

Clones	Stomatal density: Leaf blade (in a unit area of 1 mm²)	Stomatal density: Petiole (in a unit area of 10 mm²)
RRII 101	297·00 ± 13·60	3·00 ± 0·67
RRII 102	343·30 ± 6·60	3·33 ± 0·73
RRII 105	348·30 ± 6·30	3·00 ± 0·43
RRII 106	303·50 ± 6·20	4·63 ± 0·28
PR 107	332·60 ± 11·10	5·25 ± 0·95
Tjir 1	323·10 ± 7·00	4·50 ± 1·19

The organographic variability of the length and width of stomatal apertures and the clonal differences are given in Table 2 and Table 3, respectively. The aperture length of leaf blade stomata ranged from 9·96 µm (RRII 101) to 12.33 µm (RRII 105) and that of petiolar stomata ranged from 14·10 µm (RRII 101) to 18·60 µm (PR 107). The aperture width of the leaf blade stomata had a range of 1·50 µm (PR 107) to 2·20 µm (RRII 106) and that on the petiole from 3·90 µm (RRII 105) to 4·80 µm (RRII 101) respectively. The veinal stomata were noted to be intermediate in both the characters. The part to part difference was highly significant.

Table 2. *Part to part difference in the size of stomatal aperture*

Character	Leaf blade	Vein	Petiole
Aperture length µm	10·94	14·15	16·88
CD 5% level 1·26			
1% level 1·69			
Aperture width µm	1·93	3·16	4·26
CD 5% level 0·45			
1% level 0·60			

Table 3. *Clone/organographic differences in the aperture size of leaf blade, veinal and petiolar stomata*

Clones	Aperture length µm			Aperture width µm		
	Leaf blade	Vein	Petiole	Leaf blade	Vein	Petiole
RRII 101	9·96 ± 0·40	11·50 ± 0·55	14·10 ± 1·16	1·90 ± 0·13	2·50 ± 0·15	4·80 ± 0·50
RRII 102	11·60 ± 0·77	11·50 ± 0·84	14·80 ± 1·36	2·00 ± 0·47	3·40 ± 0·46	4·70 ± 0·47
RRII 105	12·33 ± 0·70	12·80 ± 0·43	14·31 ± 0·74	2·00 ± 0·13	3·10 ± 0·17	3·90 ± 0·36
RRI 106	11·30 ± 0·24	16·30 ± 0·66	17·70 ± 0·71	2·20 ± 0·15	3·10 ± 0·42	4·40 ± 0·20
PR 107	10·60 ± 0·14	16·30 ± 1·13	18·60 ± 1·12	1·50 ± 0·08	4·40 ± 0·80	4·10 ± 0·29
Tjir 1	10·50 ± 0·29	13·90 ± 0·71	17·73 ± 0·99	2·00 ± 0·19	3·80 ± 0·45	4·40 ± 0·27

A positive correlation between the aperture length of veinal stomata and that of petiolar stomata was highly significant and no other significant correlations were observed (Table 4). The aperture index of leaf blade and petiolar stomata in different clones are furnished in Table 5. The aperture index of petiolar stomata ranged from 4·23 (RRII 101) to 9·77 (PR 107) and that of leaf blade stomata ranged from 2940·30 (RRII 101) to 4284·10 (RRII 105).

Table 4. *Correlation in the length and width of stomatal apertures in the leaf blade vein and petiole*

Characters	Aperture length	Aperture width
Leaf blade vs. vein	0·05	0·05
Leaf blade vs. petiole	0·14	0·34
Vein vs. petiole	0·75**	0·02

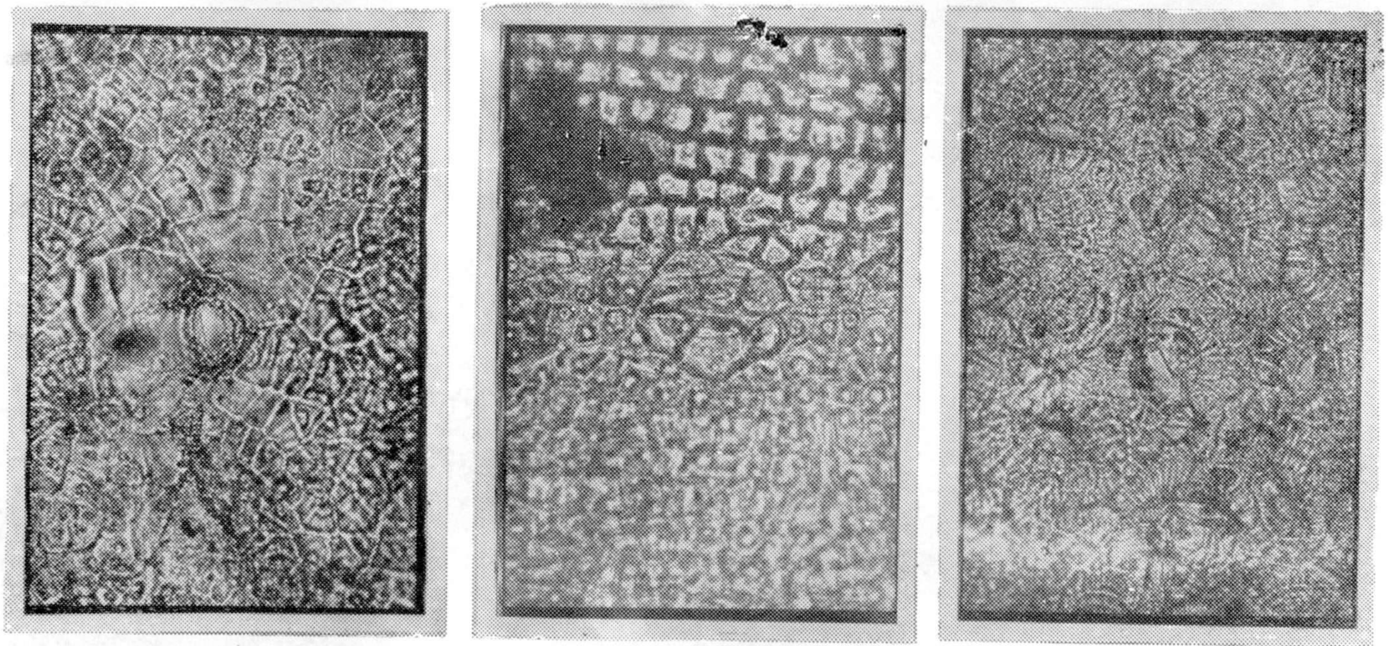
** P 0·01

Table 5. *Clonal differences in leaf blade and petiolar stomatal aperture index*

Clones	Tolerant to leaf fall disease		Susceptible to leaf fall disease Clones		
	Petiolar stomatal index	Leaf blade stomatal index		Petiolar stomatal index	Leaf blade stomatal index
RRII 101	4·23	2940·30	RRII 106	8·21	3429·60
RRII 102	4·93	3982·30	PR 107	9·77	3525·60
RRII 105	4·29	4284·10	Tjir 1	7·97	3392·26
	4·48±	3735·60±		8·65±	3449·30±
	0·22	259·70		0·56	39·70

The fruit wall stomata were characterised by long apertures comparable to petiolar stomata and the opening was very wide (Fig. 1).

The clones studied had been grouped into two categories based on the field observations on abnormal leaf fall. From field observations it was found that RRII 101, RRII 102 and RRII 105 had a certain extent of tolerance to abnormal leaf fall disease, whereas the other three were highly susceptible, under normal prophylactic conditions. Earlier reports on clonal susceptibility to abnormal leaf fall disease in *Hevea brasiliensis* also support this view (Bhaskaran Nair *et al.*, 1975 ; Radhakrishna Pillai and Chee, 1968).



(a) (b) (c)

Fig. 1. The epidermal peelings with stomata.

Fruit wall (a) Petiole (b) Leaf Blade (c)

It was also interesting to notice a part to part difference in the structure of epidermal cells. The epidermal cells of the leaf blade have sinuous walls resulting in irregular shape. It also forms a wrinkled nature due to a large number of wall outgrowths which overlap the guard cells (Fig. 1). The epidermal cells on the petiole, vein and fruit wall are somewhat regular in shape and the wall outgrowths are absent except in the region of tertiary veins.

Ramayya and Jagannatha Rao (1969) had emphasised the importance of investigating the entire stomatiferous area of a plant and the response of a given plant part to a function according to its stomatal variations. The present study brings to the fore the occurrence of stomata on the vein and fruit wall other than the leaf blade and petiole and it reveals the organographic variability in stomatal density and aperture size. Premakumari *et. al.*, (1979) had reported the occurrence of stomata on the petiole of *Hevea brasiliensis* where the clonal differences in stomatal characters and their importance in clone selection were described.

In *Hevea* the abnormal leaf fall disease is preceded by fruit rot disease which is caused by the same organism and the leaf infection starts first on the petiole (Thankamma *et. al.*, 1975). The nature of organographic variability in the density and aperture size of stomata and the structure and orientation of epidermal cells recall the organographic specificity of infection site of fruit rot disease and abnormal leaf fall disease and it appears to be linked with the mode of entry of *Phytophthora* spp. in *Hevea brasiliensis* reported by Thankamma *et. al.*, (1975).

The clonal differences regarding the aperture index of petiolar and leaf blade stomata was another interesting feature. Of the six clones under study, those which have some extent of tolerance to abnormal leaf fall disease were characteristic with low aperture index of the petiolar stomata. The observation is reflected in Table 5 where the group mean of tolerant clones is $4 \cdot 48 \pm 0 \cdot 22$ as against $8 \cdot 65 \pm 0 \cdot 56$ in the susceptible group.

The present study reveals a close relationship between the organographic specificity in stomatal characters, their clonal differences, the structure and orientation of the epidermal cells in different parts and also the part to part specificity of infection as well as the clonal susceptibility to abnormal leaf fall disease. The above information has strengthened the earlier findings that the aperture index of petiolar stomata can be taken as a criterion for the selection of *Hevea* clones tolerant to abnormal leaf fall disease (Premakumari *et. al.*, 1979).

ACKNOWLEDGEMENTS

The authors are thankful to Dr M. R. Sethuraj, Director of Research for his keen interest in the study.

REFERENCES

BHASKARAN NAIR, V. K. ; GEORGE, P. J. AND SARASWATHY AMMA, C. K. (1975). Breeding improved *Hevea* clones in India. *Proc. int. Rubb. Conf., Kuala Lumpur 1975*, pp. 45 — 54.

BOBILIOFF, W. (1923). Anatomy and Physiology of *Hevea brasiliensis* 1, Art, Institute Orell Fussli. pp. 132 — 134.

CHEN (Shiqin) etc. (1981). A study on stomata condition of rubber leaves. *Chinese J. Trop. Crops.* **2**, 76 — 83.

PANIKKAR, A. O. N. (1974). Anatomical studies in *Hevea brasiliensis* Muell. Arg. Summary of the Ph. D. work.

PREMAKUMARI, D., ANNAMMA, Y. AND BHASKARAN NAIR, V. K. (1979). Clonal variability for stomatal characters and its application in *Hevea* breeding and selection. *Indian J. Agric. Sci.* **49**, 411 — 3.

PURVIS, M. J., COLLIER, D. C. AND WALLS, D. (1966). *Laboratory Techniques in Botany*, 2nd ed. 174 pp. Butterworths, London.

RADHAKRISHNA PILLAI, P. N. AND CHEE, K. H. (1968). Susceptibility of *Hevea* rubber clones to leaf fall disease caused by two species of *Phytophthora*, *Rubb. Bd. Bull.* **10**, 95 — 7.

RAMAYYA, N. AND JAGANNATHA RAO, (1969). Range of structural and ontogenetic stomatal variations in three species of *Oscimum*. *Curr. Sci.* **38**, 79 — 82.

SENANAYAKE, Y. D. A. AND SAMARANAYAKE, P. (1970). Intra-specific variation of stomatal density in *H. brasiliensis* Muell. Arg. *Q. Jl. Rubb. Res. Inst. Ceylon*, **46**, 61 — 8.

THANKAMMA, L., RAJALAKSHMI, V. K. AND RADHAKRISHNA PILLAI, P. N. (1975). Mode of entry of *Phytophthora* in *Hevea brasiliensis*. *Proc. int. Rubb. Conf. Kuala Lumpur, 1975.* pp. 213 — 6.

FACTORS INFLUENCING THE SPREAD OF BARK ROT IN *HEVEA* CAUSED BY *PHYTOPHTHORA MEADII*

A. de S. Liyanage, Indranee Liyanage, E. B. Fernando and A. Dharmaratne
(*Rubber Research Institute of Sri Lanka*)

ABSTRACT

The spread of bark rot caused by Phytophthora meadii *is closely associated with the production of rubber pods. It was observed that there was more infection on trees bordering the roads and open spaces where the trees bore more pods. A highly concentrated spore suspension caused more damage to the bark than a lower concentration. However, 10 zoospores per ml was sufficient to initiate an infection in the bark on mature trees. Infection can be caused by injuring the bark after dipping the tapping knife in a spore suspension, but under field conditions the disease was not transmitted from infected to healthy trees through the tapping knife. Tapping panels of the clone PB 86 were susceptible up to 72 h after injury with Michie Golledge and Jebong knives, when the scrap was retained. The injuries caused by both knives succumbed to infection 96 h after tapping, when the scrap was removed prior to inoculation. There was no significant difference in the size of the lesion when trees were tapped with either knife. Increasing the depth of tapping led to greater spread of the disease. In artificially inoculated trees daily and alternate daily tapped trees succumbed to the disease and those tapped on every fourth day were not affected. Virgin panels were more susceptible than renewed panels. The spread of the fungus was greater above than below the tapping cut. In virgin panels the height of the tapping cut had no bearing on the spread of the disease when artificially inoculated but naturally infected trees showed a high incidence of panel infection close to ground level. The disease spread more during the wet than in dry months. The gutter-type rainguard initially helped to reduce the lesion size but later increased it appreciably in trees protected with them. The use of the skirt-type rainguard prevented panel infection completely. The fungus was isolated readily from the surface of the wood; but the frequency of isolation from within the wood was low up to a depth of 5 mm, beyond which it was never isolated. There was a wide variation in the susceptibility of clones to bark rot; RRIC 52, 100, and 102 being more tolerant than the other clones. Clones which were susceptible in wet districts, showed a high degree of resistance under drier conditions.*

INTRODUCTION

Among the various diseases affecting the tapping panel of the rubber tree, *Hevea brasiliensis* Muell. Arg. bark rot caused by the fungus *Phytophthora meadii* McRae or *Phytophthora palmivora* (Butl.) Butl, is the only disease of economic importance in Sri Lanka. This disease is also commonly referred to as black stripe, black thread, stripe canker and patch canker depending on the type of symptoms it produces on the bark or the wood. The fungus gains entry into the tapping cut through a wound (Peries, 1965). During periods of wet weather it spreads both above and below the tapping cut, causing considerable damage to the bark, often giving the panels a fluted appearance due to uneven callusing, which makes subsequent tapping difficult. The disease can be controlled by the application of fungicides (Peries 1965 ; Liyanage *et al*, 1977 & Liyanage, 1982) but little information is available on the factors that influence the spread of the disease. Therefore, some of the more important factors were studied and are reported in this paper.

MATERIALS AND METHODS

Natural spread: A survey was conducted in several rubber growing estates, after the monsoon rains, during a bark rot prevalent year to record the pattern of natural spread of the disease. The height, from bud union up to 90 cm on the tapping panel, at which the disease symptoms were detected was also noted.

Inoculum preparation: The zoospore suspension was prepared by scraping the superficial sporangia from 7-day old cultures of *P. meadii* grown on Difco lima bean agar (LBA) in petri dishes at 28 + 2°C (room temperature), into a known volume of sterile distilled water. This was placed in an incubator at 20°C for 30 min, then on the laboratory bench at room temperature for 10 min, to release zoospores. The suspension was agitated with a sterile rod and extraneous matter was removed by filtering through two layers of sterile muslin cloth. The zoospore concentration of the suspension was determined by the use of a haemocytometer and standardized to give 100,000 per ml, for all the experiments except one, where it was varied to give different concentrations.

Inoculation: Trees of clone PB 86, grown at Dartonfield Estate, Agalawatta, were used for all experiments except when evaluating the susceptibility of different cultivars to bark rot in budwood nurseries and inoculation of younger trees on virgin bark. Trees selected for inoculation were tapped in the morning to cause a fresh injury. Sterile absorbant cotton wool strips (15 × 1 cm) were saturated, each with 6 ml of the zoospore suspension, in large sterile petri dishes. These were taken to the field immediately after treatment and placed on the tapping cut, after the removal of the panel scrap. The panels were sealed off with budding tape, the upper edge of which was pasted to the tree leaving the bottom end free to allow for free air circulation as described by Liyanage *et al* (1977). For some experiments the panel scrap was retained prior to inoculation.

Some inoculations were done using the disc method (Satchuthananthavale *et al*, 1974) where 2·5 cm diameter bark plugs were removed and inoculated with sterile absorbant cotton wool plugs of the same diameter, saturated with 2 ml of the standardized zoospore suspension.

Trees fitted with rainguards were inoculated by pouring 10 ml of the standardized zoospore suspension per tree above guards.

The trees inoculated by the strip and disc methods were examined 4 weeks after inoculation by exposing the bark around the point at which inoculum wads were placed. The lesions were traced on paper from the trees and the area infected was measured using a planimeter.

Re-isolation: The depth of penetration of the fungus in the wood was determined by plating slivers of wood, removed at different depths, on 2 % LBA, in petri dishes.

RESULTS

Natural spread: It was observed that a large number of infected trees were present in areas bordering roads, open spaces and streams which bore pods in abundance (Fig. 1).

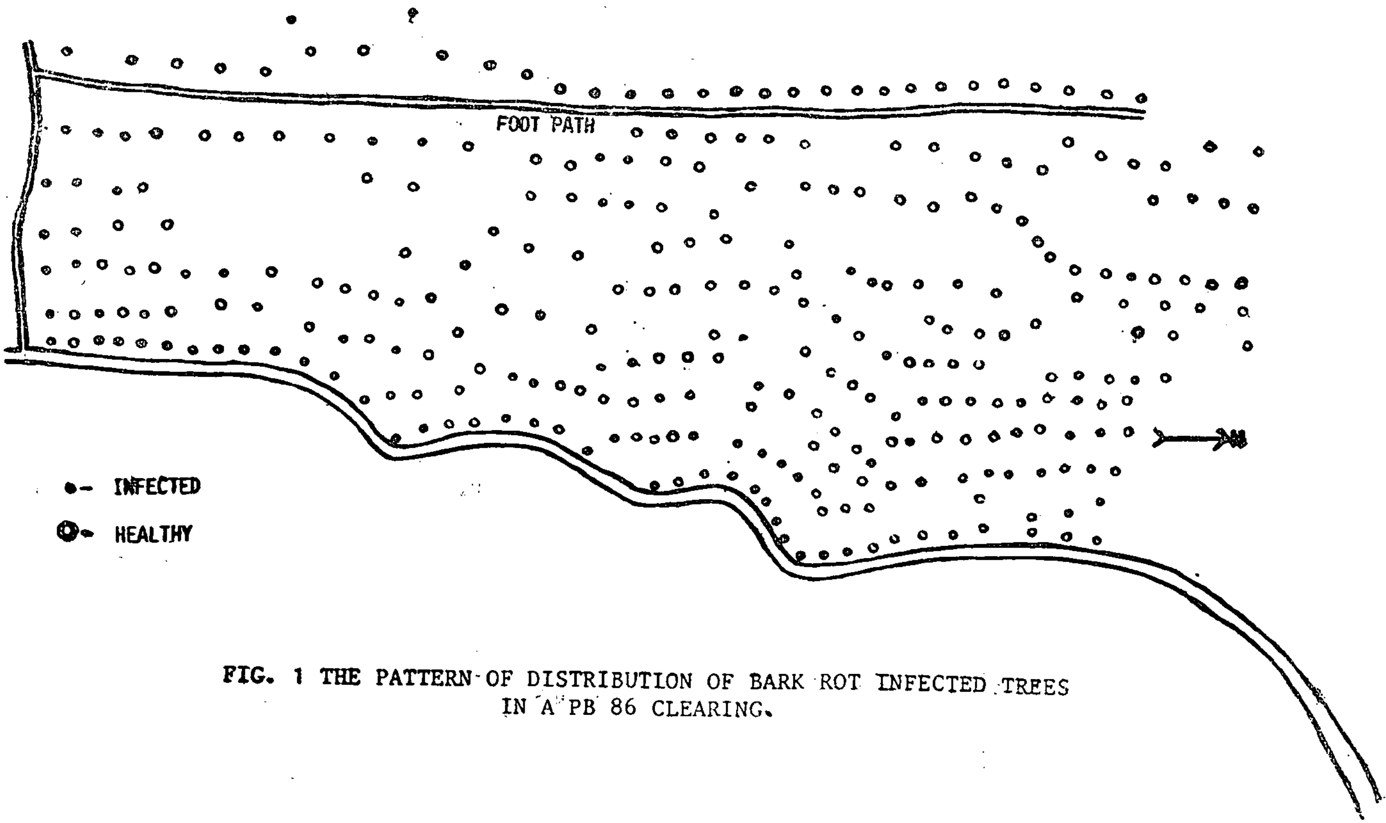


FIG. 1 THE PATTERN OF DISTRIBUTION OF BARK ROT INFECTED TREES IN A PB 86 CLEARING.

Most of the infected trees contained rubber pods which were actively producing inoculum. Usually large green mature pods were the main sites of infection but some small pods were also heavily infected under field conditions, providing inoculum (Fig. 2). A few neighbouring trees showed disease symptoms even in the absence of infected rubber pods suggesting that inoculum splashed from infected trees close by was the sources of infection. On a few occasions, immature trees in clearings planted in the lower slopes of the valley were found to be infected from the inoculum produced on the pods of mature trees, situated on the upper regions of the hill. This indicated that inoculum can be carried to a limited distance in rain drops in the direction of the prevailing wind, towards lower slopes.

Spore concentration : Even though 10 zoospores per ml was sufficient to cause infection of tapping panels in mature trees, the spread of the disease was significantly higher when the spore concentration was increased up to about 10,000 zoospores per ml (Table 1), thereafter the difference was not significant. However, at higher spore concentrations there was an increase in the lesion size.

Table 1. *Effect of spore concentration on the spread of* P. meadii

Zoospore concentration (per ml)	Mean lesion area (cm^2)
10	2·0
100	10·1
1,000	28·4
10,000	56·0
100,000	76·3
250,000	85·2
500,000	101·9
S.E.(+)	8·7
LSD (P = 0·05)	24·3

Susceptible period : Panels were infected if tapping was done after dipping the knives in an active spore suspension. This was caused by transmission of spores held by surface tension at the cutting edges of tapping knives. However, it was not possible to transfer the disease from an infected to a healthy tree under field conditions.

The effect of the retention and removal of panel scrap on infection and spread of the disease, when the bark was injured with two different knives is shown in Table 2.

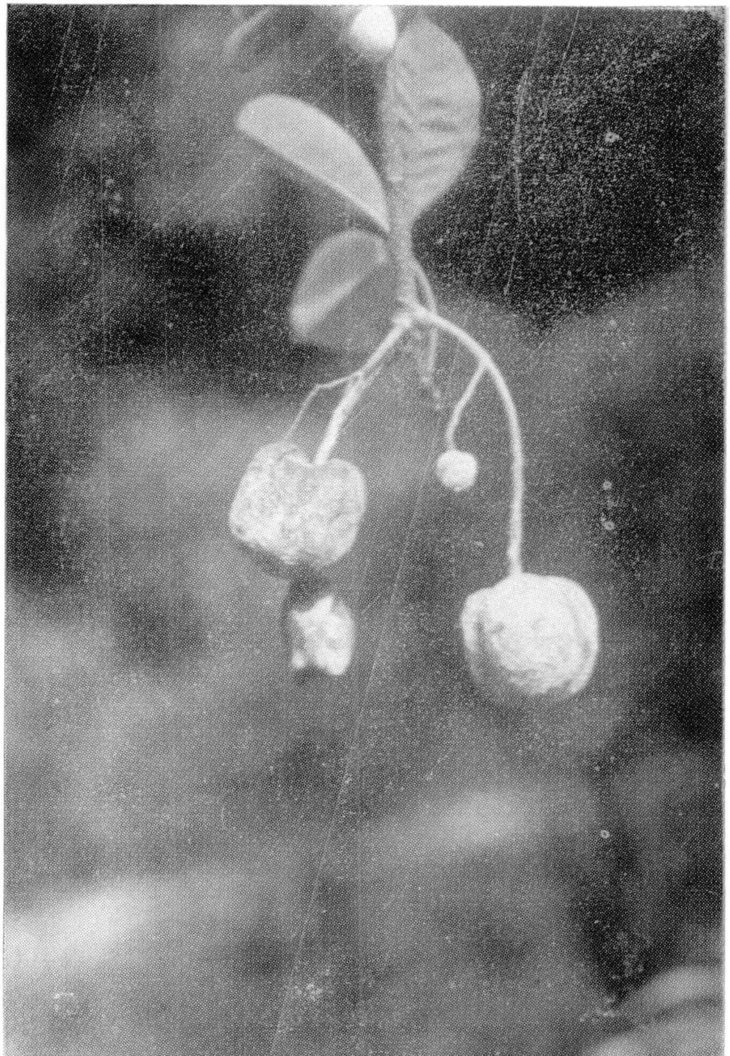


Fig. 2. Infected rubber pods, producing inoculum.

Table 2. *The infection (%) and spread (cm²) of the disease after retention or removal of panel scrap on injury using two types of knives*

Period after injury (h)	Jebong				Michie Golledge			
	scrap retained		scrap removed		scrap retained		scrap removed	
	infection	spread	infection	spread	infection	spread	infection	spread
24	100	8·3 + 1·3	100	14·0 + 1·3	100	6·0 + 0·8	100	14·6 + 1·0
48	80	1·1 + 0·3	80	1·9 + 0·5	60	0·5 + 0·3	100	3·7 + 0·8
72	80	1·1 + 0·4	100	4·1 + 0·5	80	0·6 + 0·3	100	5·6 + 0·6
96	0	0	100	2·7 + 0·6	0	0	100	2·2 + 0·5
120	0	0	0	0	0	0	0	0

It was observed that infection occurred on panels injured with both knives only up to a period of 72 h when the scrap was retained. This period was extended up to 96 h, when the scrap was removed from the panels. At 120 h after injury there was no infection, irrespective of whether scrap was removed or retained, suggesting that wounds have been completely callused by that time. The maximum spread of the fungus occurred on panels inoculated 24 h after injury, with both knives. This effect was more pronounced when the inoculation was done after the scrap was removed. The spread of the fungus was significantly less after a 48 h period when the scrap was retained, but its removal caused fresh wounding which increased the susceptibility slightly up to 96 h after inoculation. Failure of the pathogen to colonise the bark at 120 h after injury confirmed that in the clone PB 86, wound barriers sufficient to preclude infection are formed only on the 5th day after inoculation.

Tapping knife : Tapping panels were inoculated 24 h after causing injury with a Jebong (J) and Michie Golledge (MG) knives (Table 3).

Table 3. *Effect of tapping knives on the spread of* P. meadii

Type of tapping knife	Mean lesion area (cm^2)
Michie Golledge (MG)	28·9
Jebong (J)	39·4
S.E. (+)	6·4

The wounds caused by both knives were equally susceptible and no significant difference was observed on the spread of the pathogen. When the MG knife was used its vertical cutting edge caused damage to the renewing bark, in addition to the exposure of tissue in the soft bark by the horizontal cutting edge. It was possible to control the bark consumption and damage to renewing bark by careful tapping. However, the use of the J knife allowed only very little control on the bark consumption and the resulting damage to the bark may have caused a slight increase in the spread of the fungus, although it was not significant.

Tapping depth : The spread of the fungus was significantly lower when shallow tapping was done, to cause damage only to the outer hard bark (Table 4). The outer hard bark interspersed by stone cells functioned as an effective barrier to prevent the rapid spread of the fungus. However, the parenchymatous cells in this region were affected.

Table 4. *Effect of depth of tapping on the spread of* P. meadii

Treatment	Mean lesion area (cm^2)	Standard error
Corky layer injured	0·2	+ 0·2
Cambium not injured	2·4	+ 0·4
Cambium injured	3·8	+ 0·4
Untapped	0	

However, when the depth of tapping was increased the inner tissues of the soft bark were exposed and the fungus readily gained entry to cause rapid spread of the fungus, with the maximum being recorded when the cambium was injured.

Depth of penetration : The frequency of recovery of *P. meadii* at different depths in the wood of virgin and renewed panels is shown in Table 5.

Table 5. *Frequency (%) of recovery of* P. meadii *at different depths in the wood*

Type of tapping panel	Depth (mm)			
	0	2	5	7
Virgin (BO — 1)	100	50	50	0
Renewed (BI — 1)	65	60	40	0

The pathogen was easily recovered from the surface of the wood in virgin panels, but in renewed panels the frequency of recovery was slightly less. The fungus can apparently penetrate to a depth of 5 cm in the wood, but no further ; because its rate of recovery was almost the same at 2 and 5 cm, but nil at 7 cm, although the wood was discoloured at that depth.

Tapping systems : Daily and alternate daily tapping caused significantly more infection than tapping on every third day (Table 6).

Table 6. *Effect of tapping systems on the spread of* P. meadii

Tapping system	Mean lesion area (cm^2)
S/2 d/1	29·1
S/2 d/2	22·8
S/2 d/3	9·7
S/2 d/4	0
LSD (P = 0·05)	9·2

There was no infection on panels tapped on every fourth day, confirming the observation that in the clone PB 86, wounds take 4 days to callus (Table 2). However, when a fresh injury was caused to the tapping panels irrespective of the period of rest, infection occurred easily when the inoculum was supplied.

Panel susceptibility : Virgin panels were significantly more susceptible to infection than renewed panels (Table 7).

Table 7. *Effect of type of tapping panel on the spread of* P. meadii

Type of tapping panel	Mean lesions area (cm^2)
Virgin (BO — 1)	224·1
Renewed (BI — 1)	31·3
LSD (P = 0·05)	31·7

When the bark was pared off to trace the infection, it was observed that the spread was much greater above the tapping cut than below it. When the virgin panels were inoculated at 30, 60, 90 cm from the bud union, no significant difference was observed on the lesion size indicating that height had no influence on the spread of the disease when artificially inoculated.

In areas severely affected by abnormal leaf fall, occurrence of bark rot on both panels was a common feature (Fig. 3). This was due to the change over of panels during this period, when heavily infected pods were present. It was observed on several occasions that the second panel was tapped only after the one being tapped was rested after surgical treatment. The continuation of tapping on the other panel exposed it to infection and its treatment often led to ring barking of the tree, resulting in its death. The damage was extensive if both were virgin panels. Therefore, it is important not to open trees for tapping during wet weather in areas which are subject to an attack of abnormal leaf fall.

Age of cultivars : Overall the spread was low in the virgin panels inoculated at 189 cm above the union but the spread of the disease was significantly higher in virgin panels in younger trees than in the older ones (Table 8). Trees with tapping panels on virgin bark were not available for a simultaneous inoculation, but inoculation of virgin bark of younger trees separately in another location showed that the spread of the disease was much greater in them.

Table 8. *Effect of the age of trees on the spread of* P. meadii

Year of planting	Mean lesion area (cm^2)
1956	24·7
1957	27·4
1958	31·2
1959	93·7
1960	86·0
LSD (P = 0·05)	28·8

However, when naturally infected trees were surveyed (Fig. 4), it was observed that there was an increase in the incidence of the disease in panels where the tapping cut was close to the ground and this effect was reduced as the height increased. Such infections were observed towards the latter part of the leaf fall phase of disease.

Fig. 3. A tree severely affected with bark rot.

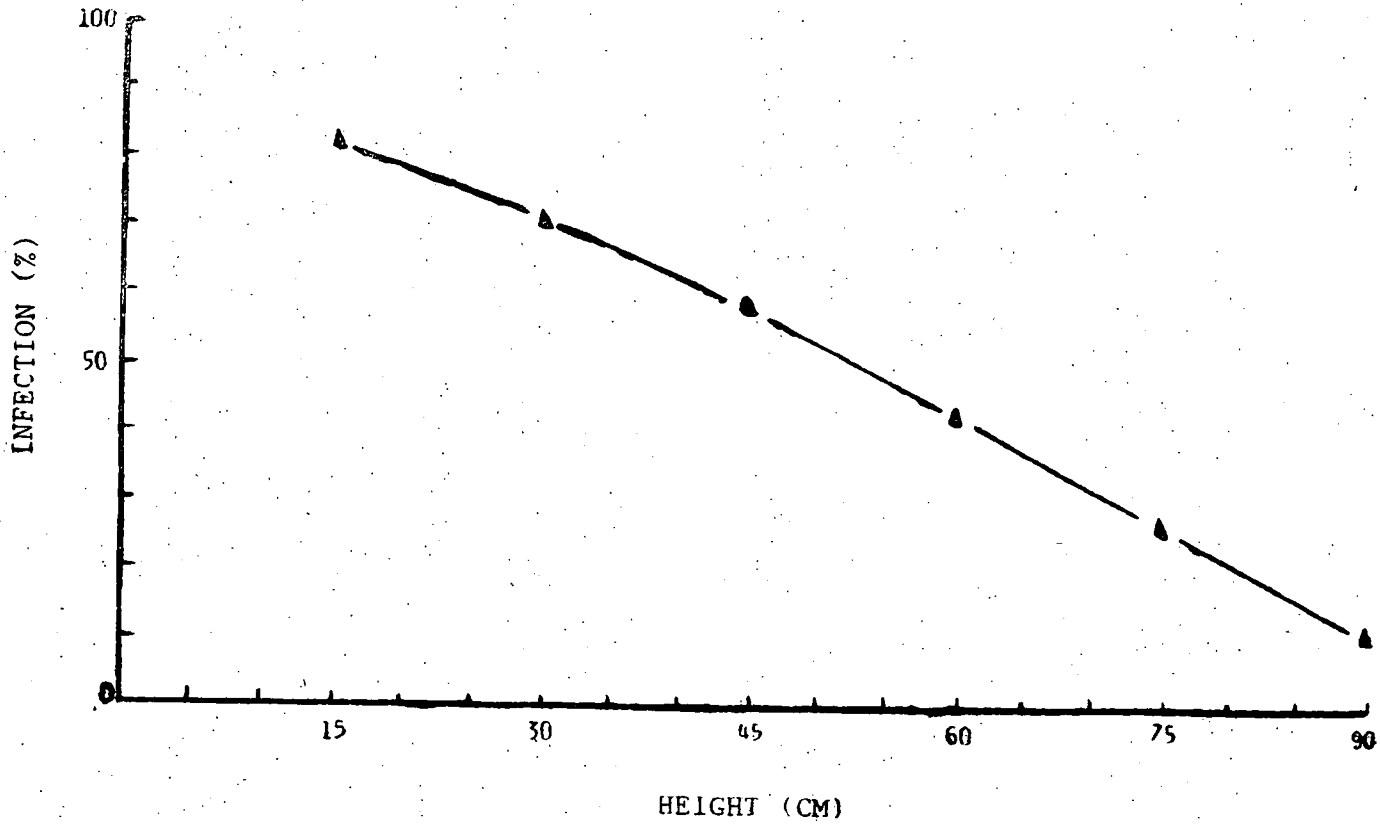


FIG 4 BARK NOT INFECTED AT DIFFERENT HEIGHTS FROM THE BUD VERSION.

Seasonal variation : The results of the inoculations carried out monthly over a period of 1 year are shown in Table 9.

Table 9. *Spread of bark rot caused by* P. meadii *in renewed panels*

Month	Mean lesion area (cm^2)
January	0·7
February	2·6
March	3·1
April	6·4
May	10·3
June	21·0
July	16·1
August	5·8
September	6·2
October	12·8
November	14·5
December	1·8

The spread of the disease was highest during the months when the south-west and north-east monsoon rains fell ; but during the intervening dry months the spread was less, with the lowest being recorded in the driest months of December, January and February.

In another experiment several trees of clone PB 86 were inoculated in June and a few trees were examined on each subsequent month. It was observed that the spread was high in the months of June and July, but it was difficult to trace the infection from August onwards without cutting into the wood that callused over the wounds. The spread of the fungus was limited during the dry periods. When these trees were left without any treatment, knotty growth was seen on the panels and there was no indication that these lesions initiated new infections later with the onset of rains.

Effect of rainguards : The effect of rainguards on the incidence of bark rot is indicated in Table 10.

Table 10. *Effect of rainguards on the spread* (cm^2) *of* P. meadii.

Type of rainguard	Period after fixing (weeks)		
	4	8	20
Gutter	39·4	21·5	87·1
Skirt	0	0	0
Control	53·1	54·8	132·7

Initially the gutter-type rainguard allowed relatively little infection compared to the control but later leaks caused by the cracks that developed at the point of fixing rainguards to trees allowed part of the inoculum dripping down the trunk to seep through the cracks to cause panel infection. The skirt-type rainguard on the other hand, completely protected the panels from bark rot infection and this effect lasted upto 20 weeks after fixing the rainguards. The inoculum poured did not get into the panel at the point of attachment of rainguards to the tree, but was diverted away from it. This helped to keep the disease out from trees fitted with the skirt-type rainguard.

Clonal susceptibility : The effect of susceptibility of different clones to bark rot infection is shown in Table 11.

Table 11. *Susceptibility of different clones to bark rot caused by* **P. meadii**

Clone	Mean lesion area (cm^2)
RRIM 600	25·4
RRIC 36	22·0
GT 1	20·7
IRCI 7	20·7
PR 107	20·0
PB 86	19·7
IAN 717	18·6
RRIC 102	15·2
GL 1	13·3
RRIC 100	12·5
RRIC 52	12·1
FX 3221	9·4

None of the clones were immune but they showed differential susceptibility with some of the high yielding clones bred in Sri Lanka, Malaysia, Indonesia and Ivory Coast being most susceptible. Clone PB 86 is moderately susceptible and RRIC 52 was tolerant to the disease. The progeny that resulted from crossing these two cultivars was highly tolerant to the disease, suggesting that it would be an ideal clone for the wet areas. On the other hand, high yielding clones such as RRIM 600, RRIC 36, GT 1 and PR 107 were all very susceptible to bark rot infection and their planting should not be done in excessively wet areas.

Effect of environment : The behaviour of clones of differential susceptibility under varying environmental conditions was assessed by the disc method and the results are shown in Table 12.

Table 12. *Effect of different environments on the susceptibility of clones to* P. meadii.

Clone	Mean lesion area (cm^2) wet districts	Mean lesion area (cm^2) dry districts
RRIC 36 (S)	13·5	4·8
RRIM 600 (S)	15·4	5·5
RRIC 100 (T)	10·2	4·9

S = susceptible T = tolerant

Clones which were highly susceptible to bark rot in the wet areas showed relatively little infection in the drier areas. There was a significant difference between clones and also between environments. The clone X environment interaction was also significant, showing the importance of selecting clones on a regional basis depending on the environmental conditions.

DISCUSSION

Trees bearing large numbers of infected pods affected with bark rot were found mostly in areas by the sides of roads, open spaces and streams. This close relationship between pod set and incidence of bark rot has been previously reported (McRae, 1918 ; Peries, 1969 ; Satchuthananthavale, 1971 ; Liyanage *et al*, 1983). The fungus hibernated on stems and pod stalks of infected trees (McRae, 1918 ; Peries, 1967 ; Tsao *et al*, 1976), and this explains the reason for the recurrence of the disease in the same locality. It was demonstrated by Liyanage (1970) that soils play an important role in the survival of *P. meadii* for a limited period, in areas where leaf fall had occurred. Conclusive evidence for this has been provided by Liyanage (1984) who has shown that the fungus can survive in the soil as chlamydospores for long periods. When it rains panel infection can occur by spores splashed from the soil. This perhaps accounts for the high incidence of the panel disease close to the ground level. These observations suggest that *Phytophthora* leaf fall and bark rot are unlikely to spread beyond its known occurrence. Nevertheless, it is essential to monitor the disease development to detect it at an early stage, especially in areas adjacent to infected areas, so that proper preventive and curative measures can be taken in time.

Bark infections occur mostly during periods of heavy rain in May-July and October-November. Most of the new infections occurred during the south west monsoon when mature pods were present and free water was available for propagation and dissemination of spores (Peries, 1975). However, when pod formation was delayed and protracted new infections occurred in October-November and in some exceptional years even in December. This occurred only when there was sufficient rain at that time but the disease never reached epidemic proportions because the supply of inoculum was minimal, as most of the pods had dehisced by that time. There was limited spread of the fungus in the bark during the dry months that followed the north-east monsoon period. Therefore, the critical period for bark rot infection was from May-July and prophylactic application of fungicides must be confined to this period. The recommended fungicides include 1·2% Antimucin, 1% Fylomac 90, 15% Brunolinum plantarium (Peries, 1965), 0·8 — 1·6% Difolatan, 0·2 — 0·4% Ridomil (Liyanage, 1982), also showed that Aliette gave good results in preliminary trials. If there was panel infection during the south-west monsoon season, application of fungicides has to be extended from May-December, to prevent the spread of the fungus during the north-east monsoon rains. If panels get infected during the north-east monsoon, the application of fungicides should be limited to that period. Peries (1975) found that an equivalent of 0·1 inch rain reduced the efficacy of the fungicides by at least 25 per cent. Therefore, a second application was essential if there was rain interference but the use of rain-fast formulations that have been tried (Liyanage, *et al*, 1977) offer better prospects for controlling the disease. Fungicides should be applied on the day of tapping, preferably at collection or at the earliest opportunity if wet weather precludes this operation, as recommended by Peries (1965).

The minimum spore concentration required to cause an infection in the bark was 10 zoospores/ml confirming the findings of Satchuthananthavale (1971) and Peries (1975). However, this study indicated that the spread was greater in the presence of a concentrated spore suspension indicating that extensive damage to the panels could occur when the pod set is heavy provided weather factors are conducive for development of the disease. The tapping cut remained highly susceptible to infection for a 24 h period after injury. Thereafter, susceptibility decreased rapidly and 5 days after the injury the cut was immune to infection, due to the formation of callus tissue. This observation generally agreed with those of Satchuthananthavale (1971) and Peries (1975) who have noted a susceptibility period of up to 120 h with the first 48 h being more critical for the infection. Therefore, tapping trees even during intervening dry periods between rains, when pods are actively producing inoculum can lead to panel infection.

Availability of inoculum and injury to the bark are the two essential prerequisites for panel infection. The low incidence of black stripe in India in spite of the severe leaf fall phase of the disease has been attributed to the cessation of tapping during monsoon months when pods are infected (Radhakrishna Pillai, 1969). The use of a skirt-type rainguard could also help to reduce panel infection. This will facilitate the inoculum seeping down the trunk to be diverted away from the tapping cut and it has the added advantage of preventing crop losses due to rain interference. The gutter-type rainguard is of limited use as it cannot prevent inoculum leaking through the cracks and lateral splash of water droplets containing the spores reaching the cut.

It was observed that the spread of the fungus was limited if shallow tapping was done. However, increasing the depth of tapping exposed the parenchymetous tissues of the soft bark causing them to be infected. The vertical depressions which appear just above the tapping cut can later coalesce to form a band corresponding with the seasons tapping. If the disease is not detected early or the control measures are neglected, development of vertical fissures due to uneven callusing can later prevent the proper exploitation of the tapping panel. Therefore, it is essential to recognise the disease symptoms early to prevent extensive removal of bark tissue, particularly in young trees up to 17 — 18 years after planting, when virgin bark is highly prone to the disease. The spread of the fungus is higher above the cut than below it. Therefore, downward spread can be kept under control by repeatedly tapping the panel to remove all the infected bark without excision of bark and by regular application of an effective fungicide. Renewed bark is less susceptible to infection, perhaps due to the presence of large number of stone cells in the outer bark and removal of infected tissues is not recommended unless the fungus spreads in both directions of the panel, under favourable weather conditions. The change over of panels should not be done during wet weather especially in areas which show symptoms of abnormal leaf fall. This is particularly important if one panel is already infected as infection of both panels could lead to ring barking at the time of treatment, which can eventually kill the tree. The spread of the disease was more when tapped with the Jebong then with the Michie Golledge knife, presumably due to the greater damage to bark tissues caused by uncontrolled tapping. The use of the Michie Golledge knife can be controlled, thereby minimising the exposure of susceptible tissue and it may in part be attributed to the low level of infection when tapped with that knife. The fungus is not known to be carried by the knife and its disinfection between tappings is not essential. The fungus does not penetrate deep into the wood, but it was easily recovered from the superficial layers of the wood. Therefore, during treatment it is not necessary to cut out the discoloured wood ; but a superficial scraping would suffice. Increasing the frequency of tapping during the *Phytophthora* leaf fall season can increase the risk of panel infection. Panels tapped and rested for 4 days showed complete immunity to infection. However, when these panels were tapped and inoculated they succumbed to the disease suggesting that changing the frequency of tapping to prevent bark rot infection may not be a feasible proposition.

There were marked differences in clonal susceptibility to bark rot. Therefore, it is desirable to ensure that highly susceptible clones are not planted in the predominantly wet rubber growing areas. However, some of the highly susceptible clones in wet districts can be recommended for planting in drier parts of the country. Breeding clones tolerant to bark rot with sparse pod production appears to be the most economical method of controlling the disease. Several high yielding clones with good resistance to bark rot have been bred (Fernando and Liyanage, 1976), and these could be used effectively in a hybridization programme.

ACKNOWLEDGEMENTS

We are grateful to Mr W. N. Wickramasinghe and Mr L. T. Peiris for statistical analysis of the data. Thanks are also due to Mr D. U. Kannangara for preparing the diagrams. We thank the Director Dr O. S. Peries for reading through the manuscript and for helpful suggestions.

REFERENCES

FERNANDO, D. M. AND LIYANAGE, A. de S. (1976). *Hevea* breeding for leaf and panel disease resistance in Sri Lanka. *Proc. Int. Rubb. Conf. Kuala Lumpur* 1975, 3, 236 — 250.

LIYANAGE, A. de S. (1970). Review of the Plant Pathology Department. *Ann. Rev. Rubb. Res. Inst. Ceylon.* 1969, 57 — 58.

LIYANAGE, A. de S., NADARAJAH, M., LIYANAGE, G. W. AND DANTANARAYANA, D. M. (1977). Investigations on new fungicidal systems for control of bark rot on *Hevea brasiliensis*. *Jl. Rubb. Res. Inst. Sri Lanka*, **54**, 316 — 328.

LIYANAGE, A. de S. (1982). Review of the Plant Pathology Department. *Ann. Rev. Rubb. Res. Inst. Sri Lanka*, 1981, 53 — 68.

LIYANAGE, A. de S., PERIES, O. S., DHARMARATNE, A. AND DANTANARAYANA, D. M. (1983). Effect of weather factors on disease establishment and sporulation of *Phytophthora meadii* on rubber pods. *J. Rubb. Res. Inst. Sri Lanka*. **61**, 41 — 48.

LIYANAGE, N. I. S. (1984). Unpublished data. Rubber Research Institute of Sri Lanka.

MCRAE, W. (1918). Phytophthora meadii n. sp. on *Hevea brasiliensis*. *Mem. Dept. Agr. India. Bot. Sci*. **9**, 219 — 273.

PERIES, O. S. (1965). Recent developments in the control of the diseases of the *Hevea* rubber trees. *Q. Jl. Rubb. Res. Inst. Ceylon*, **41**, 33 — 46.

PERIES, O. S. (1967). Review of the Plant Pathology Department. *Q. Jl. Rubb. Res. Inst. Ceylon*, **43**, 89 — 109.

PERIES, O. S. (1969). Studies on epidemiology of *Phytophthora* leaf disease of *Hevea brasiliensis* in Ceylon, *J. Rubb. Res. Inst. Malaya* **2**, 73 — 78.

PERIES, O. S. (1975). Factors affecting infection of *Hevea* bark by *Phytophthora species* with special reference to disease control. *Proc. Int. Rubb. Conf. Kuala Lumpur*, 1975, 199 — 212.

RADHAKRISHNAN PILLAI, P. N. (1969). Panel diseases of rubber. *Rubb. Bd. Bull*. **10**, 141 — 143.

SATCHUTHANANTHAVALE, V. (1971). Black stripe or bark rot of *Hevea*. *Q. Jl. Rubb. Res. Inst. Ceylon*. **48**, 125 — 135.

SATCHUTHANANTHAVALE, V., SATCHUTHANANTHAVALE, R. AND DANTANARAYANA, D. M. (1974). Screening of clones for black stripe disease in *Hevea*. *Proc. Rubb. Planters' Conf*. Part I. Cochin, India 5 — 8 (mimeograph).

TSAO, P. H., TUMMAKATE, A. AND BHAVAKUL, K. (1976). Recovery of *Phytophthora* species from old, badly decayed, infected tissues of *Hevea brasiliensis*. *Trans. Br. mycol soc*. **66**, 557 — 558.

SESSION 6. CLIMATE AND YIELD

THE COLLECTION AND USE OF YIELD AND CLIMATIC DATA FROM RUBBER ESTATES IN SRI LANKA

By

ANN GIBB*, A. de S. LIYANAGE**, R. D. STERN*, I. C. DALE* AND S. ABEYSEKERA***
(*University of Reading, UK*, Rubber Research Institute, Sri Lanka**, University of Colombo, Sri Lanka****)

ABSTRACT

Attempts to quantify the relationships between the yields of tropical crops and the weather have been hampered by the lack of suitable, long-term data in a computerised form. The record books maintained on rubber estates in Sri Lanka provide a good source of data for crop-weather research.

A collaborative research effort involving three institutions has made it possible to set up a system for data collation and computerisation. These institutions are the Sri Lankan Rubber Research Institute, the Statistical Unit at Colombo University, and the Tropical Agricultural Meteorology Group at Reading University, UK. Data for two variables, daily yield and daily rainfall, are being computerised at the estate level from records which span some 30 years. Other climatic variables have also been collected as monthly averages. The methods needed to check and computerise these large data sets are outlined, with emphasis on some of the problems encountered. Examples are used to show some ways in which the data can then be presented and analysed.

This is the first of three papers which discuss crop-weather relationships. This paper provides the background to some collaborative work which has made it possible to set up a computerised "data bank" at the Rubber Research Institute in Sri Lanka. The other papers examine ways of making use of this wealth of data for practical applications and research.

Experimental studies at RRI's (and other research institutes) seem to make little use of routinely collected data. Often these data sets are very reliable (as they have to be, for example, for accounting purposes). Better use could be made of the daily rubber yield records at estate level, and the corresponding daily rainfall observations. In general, the more readily available published monthly data have not been shown to be particularly useful (*e.g.* studies of wheat in the US) mainly because the process of averaging the data — either over time or over areas — loses a great deal of information, so any relationships that may exist become hidden. It is far better to look at the data at the most detailed level possible, and then 'average' the relationships, if any are found.

In Sri Lanka the situation is favourable for this type of crop-weather research. A unique source of daily data for both rubber yield and rainfall is held in the record books at many estates. The computing resources needed to deal with such large quantities of data are now becoming more widely available. Many of the statistical techniques needed are also well-developed. The rest of this paper is a brief account of the way in which some of these data sets have been collected and computerised, with some descriptive analyses of data so far collected.

Data collection

Fig. 1 shows a map of the rubber-growing regions of Sri Lanka, with an indication of some of the estates from which data have been collected. The initial intention was to collect some data from each of the main regions — Kalutara, Kegalle, Kelani Valley and Ratnapura.

Fig. 2 gives a more detailed summary of the yield and rainfall data collected. The estates chosen for computerisation first are indicated ; the selection was made from estates which (a) were known to keep reliable records, (b) had records over at least 15 years, and (c) had both rubber and rainfall records for the same periods.

The point of this summary is to emphasise the enormous amount of routine measurement and meticulous recording which has been done over the years. This effort on data collection must now be balanced by a corresponding effort on data analysis. Already about eight estates are computerised and most of the data checked. As far as we are aware this represents a unique set of crop and climate data from the tropics.

A summary of the process which is being used to enter and check the data is shown as Fig. 3. "Collection" in the sense used here, means copying, by hand, details from the record books onto printed coding sheets in readiness for keying into the computer. This was done at the estate itself. The same form has been used for both rubber and rainfall. Obviously this copying process can introduce errors, and one method used to check for this was to return to the estate with a listing of the computerised data and compare the values with the record books.

Another method used to trap errors was to compare the monthly totals, where available, with totals recalculated from the daily data. This was easy to do on the microcomputers used for data entry. On the whole this works well with the rainfall ; unfortunately, the yield figures often do not match. This difference is apparently due to the way in which metrolac measurements, taken at the collection centre each day, are rounded down to the nearest pound or kilogram. (The metrolac is a calibrated float used to assess the relative density of the latex. This density is assumed to be related in a predictable fashion to the dry rubber content). The monthly total appears to be calculated from more accurate factory weighings. The difference between the rounded-down metrolac total and the factory total (called "excess' or "overflow") can sometimes be more than the average daily yield on the estate.

It is not clear how the overflow problem can be dealt with easily for an analysis of the daily data, since its distribution through the month is not known. One possibility is that it is related in a simple manner to the number of tappers and the number of tapping days in the month. More information is required to be able to verify this.

A further aspect of data at this level of detail is the obvious effect on yields of the size of the estate. The estate area or, preferably, the total number of trees in tapping, need to be known at frequent points through the period of the record. Without such information any climatic effects on yield are difficult to identify. The nationalisation of the rubber industry in the early 1970's is another complication, through its effect on the management of estates and possibly also the accuracy of record-keeping.

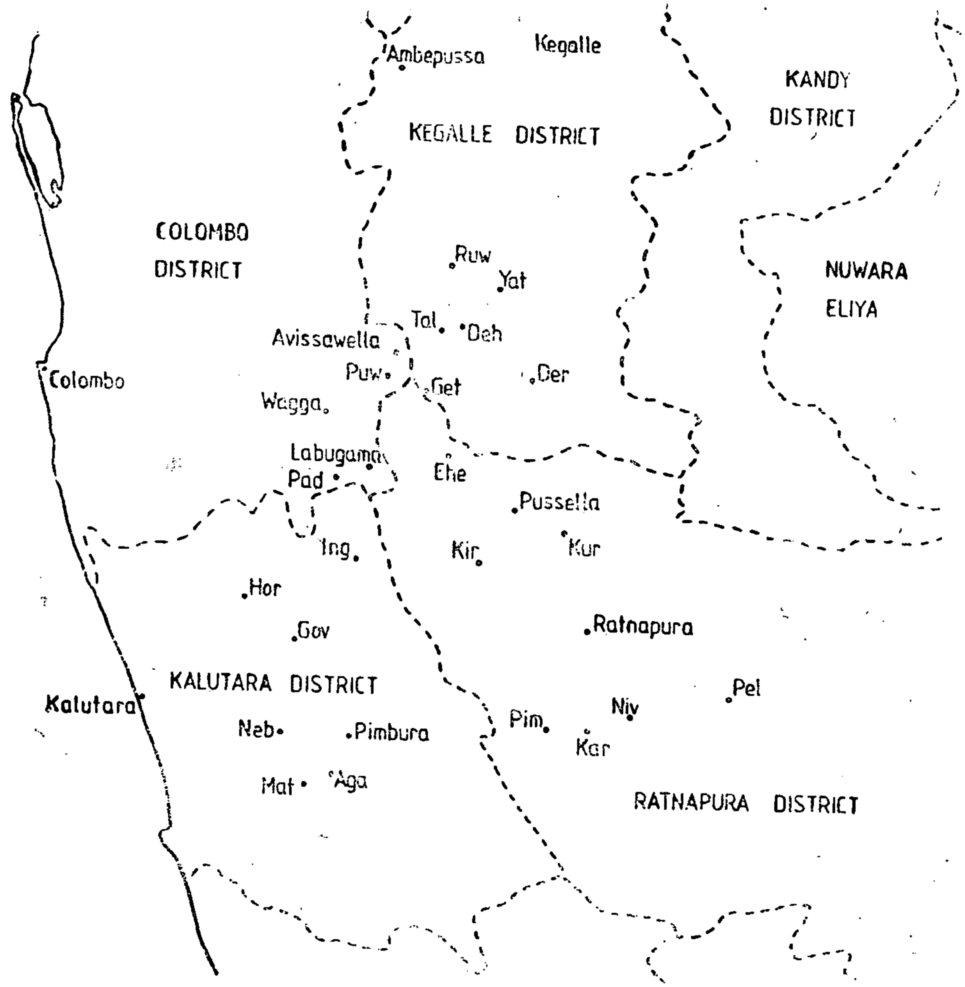


Fig. 1. Rubber growing regions of Sri Lanka.

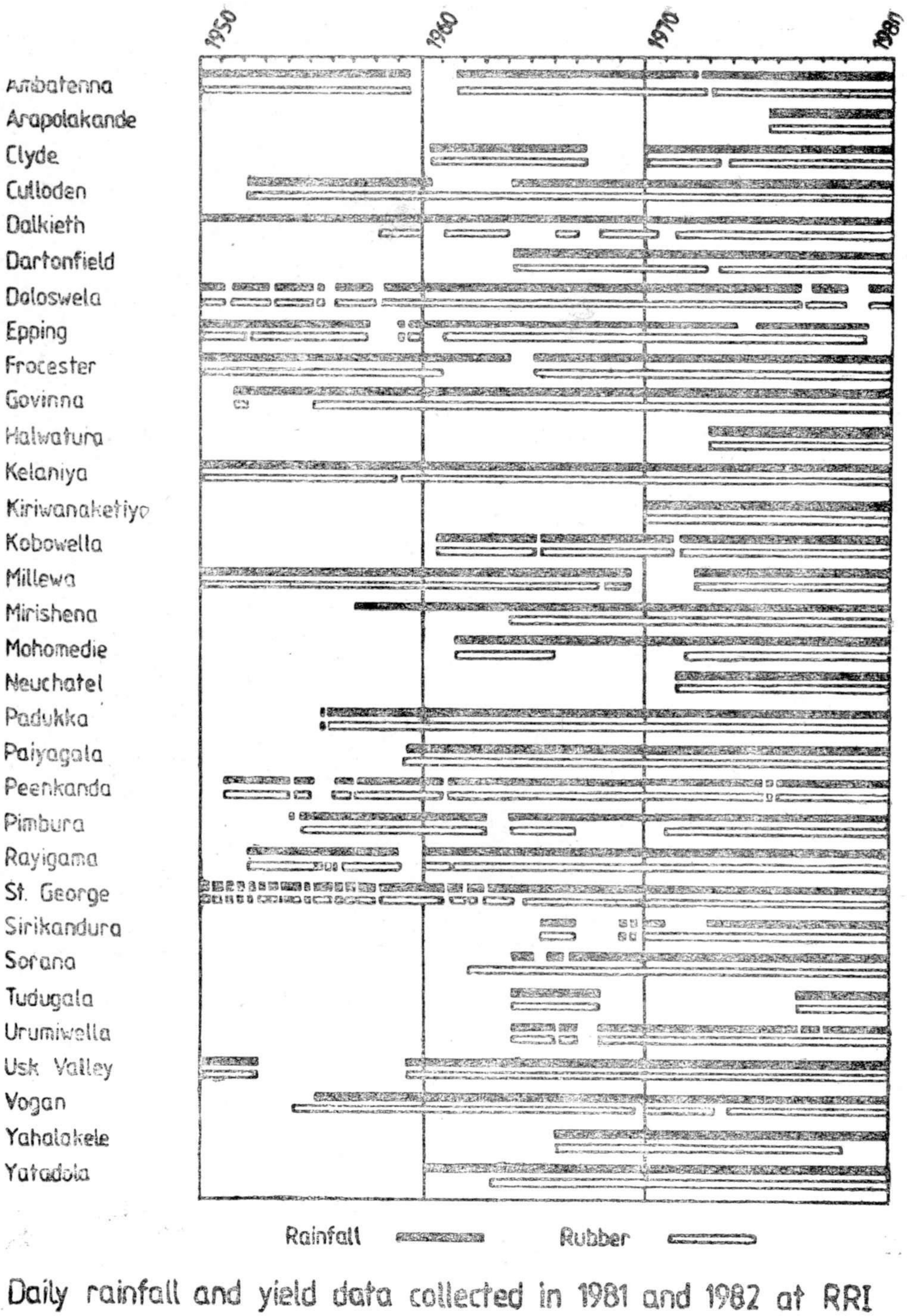


Fig. 2. Detailed summary of yield and rainfall data collected.

Recording, Collection and Computerisation of Estate Data

1. Yield and rainfall recorded daily.

2. Records copied by hand onto stencilled forms at estate. Monthly totals included where available.

3. Data on forms double-checked with estate records.

4. COLOMBO : Data entered onto University's mini-computer. Listings checked by hand with coding forms.

   READING : Data entered on a micro-computer using double-entry to prevent errors.

5. Data listings taken to estate and compared with the original estate records. Errors in copying located and marked for correction.

6. COLOMBO & READING : Corrections made to computer records.

Fig. 3. Data collection and computerisation process.

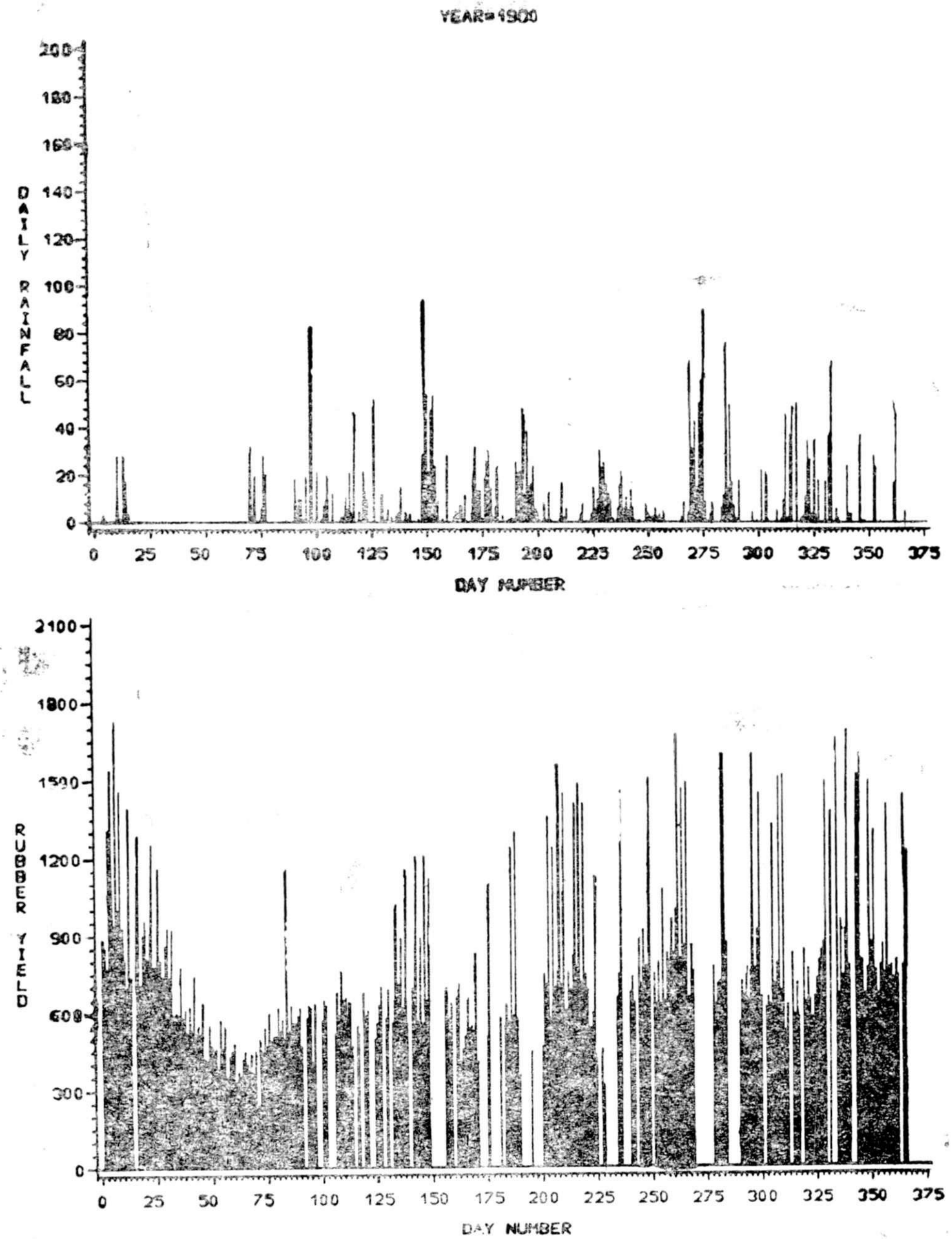
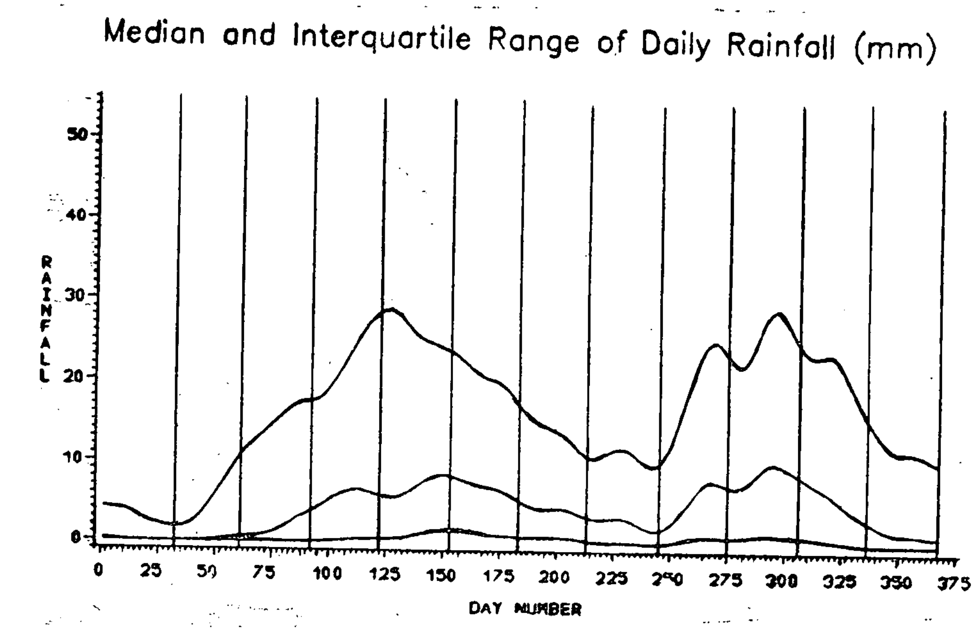


Fig. 4. Daily yield (kg) and rainfall (mm) for 1980 at Dartonfield.



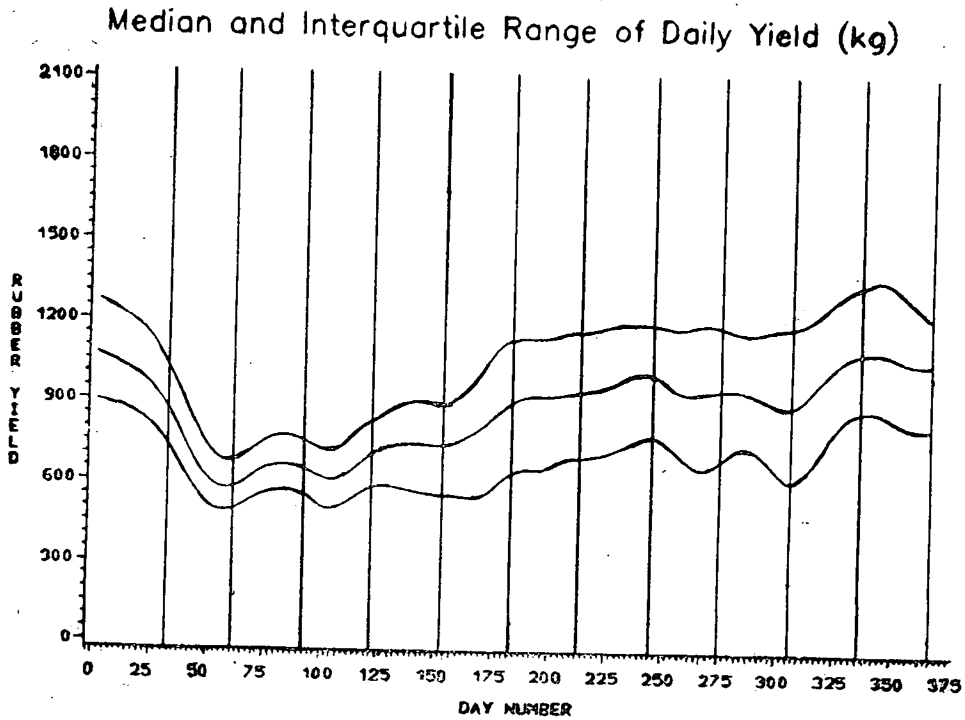


Fig. 5. Summary of daily values of rainfall (mm) and yield per tapping day (kg), for Dartonfield, from 1964 — 1982.

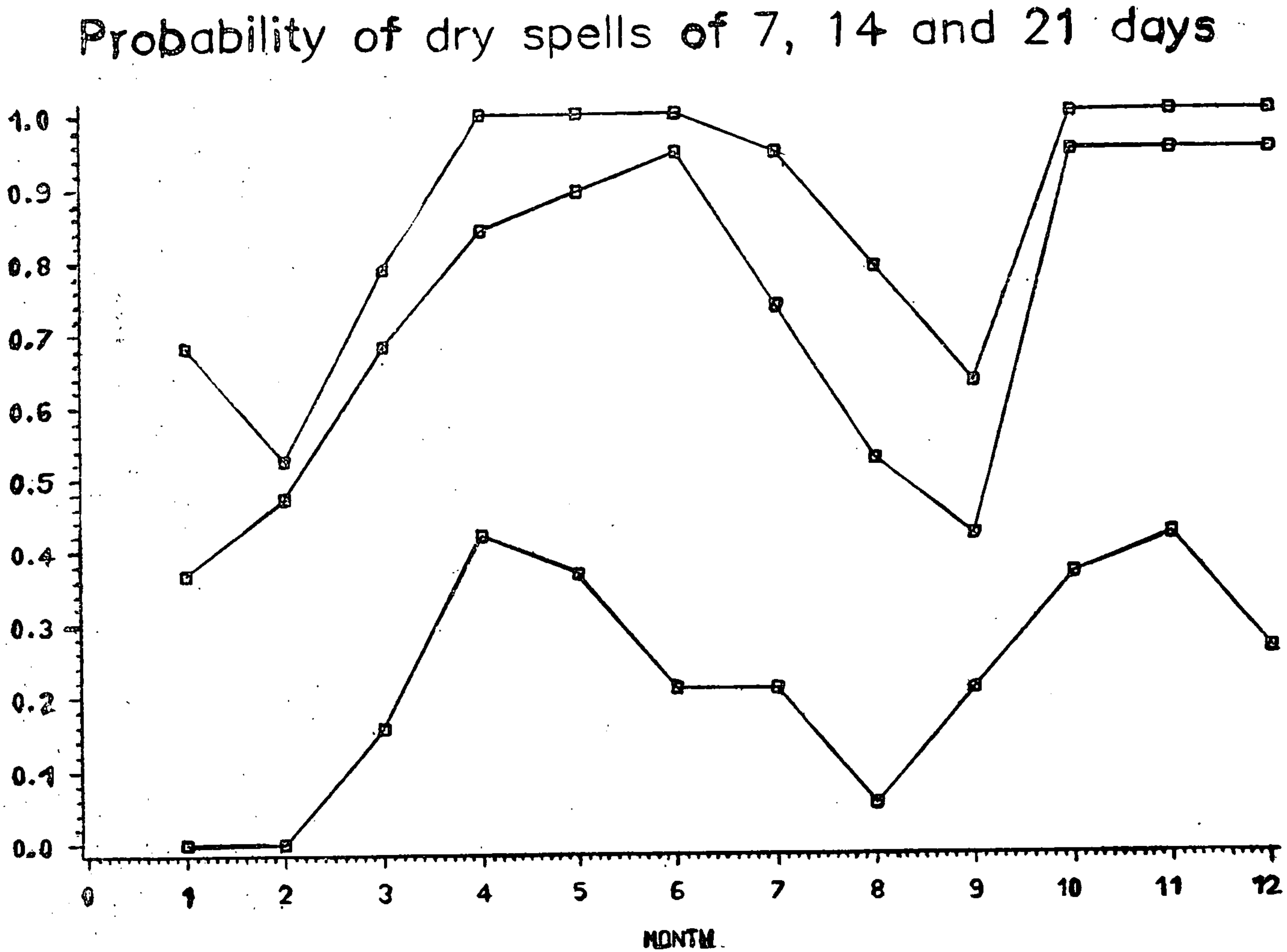


Fig. 6. Proportion of years with a dry spell of more than 7, 14 and 21 days in each month at Dartonfield.

Plans are being made to simplify the data entry and checking procedures by using a microcomputer at the estates. By this means problems which come to light can be resolved immediately, since the relevant information should be at hand. This will be combined with some programs for producing summary statistics, so that managers can immediately see the benefits.

SUMMARIES

Figure 4 shows the daily yield and rainfall for 1980 at Dartonfield Estate. Planters will be able to look at the yield and say whether or not it was "a good year" with the judgement that comes from years of experience. There is a yearly pattern to the yield ; the most pronounced feature of this is the wintering period of February to March which follows leaf-fall and refoliation in the drier months.

Once the data have been computerised and checked, the first question to ask is whether the patterns of yield and rainfall through the year can be summarised. (The second question is how are the yield and rainfall related : this is the topic of the second and third talks in this session). The average daily values of rainfall and yield per tapping day at the RRI estate are shown in Fig. 5. The 'average' used in both instances is the median, which here gives a more representative picture of the values than the mean. The interquartile range (the "middle half" of the 19 observations on each day) indicate the spread of the data. The values have also been smoothed for clarity.

A wide range of useful summaries of rainfall data are possible when daily data have been collected. Fig. 6 shows the proportion of years with a day spell of more than 7, 14 and 21 days in each month at Dartonfield. This can be interpreted as the probability of a dry spell of at least 1, 2 or 3 weeks in each month. The values are unlikely to be very accurate as they are based on only 19 observations (one per year). For this type of analysis to be used for prediction, it is necessary to assume that next year will be like the last, *i.e.* the climate is not changing. This is debateable !

CONCLUSION

There are of course many other ways in which the daily data can be summarised. These examples give only an indication of the vast potential of the data accumulating at rubber estates in Sri Lanka. One of the more important uses of the data bank should be to assist planters in the managerial decisions they face through the year. Therefore, it is for the planters to dictate how the data should be presented for practical uses. Possibly the best direction is not for researchers to attempt to provide "the answers" but instead to provide the facilities or tools which give the results.

A CROP-WEATHER CALENDAR FOR RUBBER

By

A. de S. LIYANAGE*, ANN GIBB** AND A. R. WEERASINGHE*
(*Rubber Research Institute of Sri Lanka* and University of Reading***)

ABSTRACT

Simple statistical methods were used to examine daily rainfall measurements collected from rubber estates in Sri Lanka. The purpose was to match up cultural practices of growing rubber to rainfall in a quantified way. Rainfall events which were thought to be associated with some of these practices were defined for each of such estates. Using one estate to illustrate, probability estimates for these events were made directly from their frequency of occurrence in a 28 year period. This type of analysis can be used to determine the optimum time to carry out cultural operations that are influenced by rainfall.

INTRODUCTION

Rubber (*Hevea brasiliensis* Muell Arg.) cultivation is limited mainly to the wet south-west corner of Sri Lanka and it is one of the main export crops. The reason for its confinement to this area is that the rubber plant grows well only in areas where moisture is not a limiting factor. Hence rainfall is of great concern to the rubber grower and it also affects the tree at all stages of growth from planting through to felling. Some important questions therefore are, 'When, do the rains start ?'. 'When, do they end ?'. 'How long, is the rainy season ?'. 'How, much rain will the season have ?' and 'What, risk is there of a dry spell in the rainy season ?'. This paper studies the rainfall pattern and the associated dry spell risks using simple statistical methods and is complemented by 2 other papers (Gibb *et al* 1984 a; Gibb *et al* 1984 b), all of which together belong to a crop climatic project outlined by Leaker (1982) in consultation with the staff of the Rubber Research Institute of Sri Lanka (RRISL). The aim is to provide answers to the above questions and more importantly to show how these can be used to determine the optimum times for carrying out the various cultural operations involved in rubber cultivation.

MATERIALS AND METHODS

Daily rainfall data were collected from various rubber estates from the three main rubber growing districts in Sri Lanka, namely, Kalutara, Kegalle and Kurunegala. The data collected from six of these estates, in the Kalutara District, were computerised by coding, entering, checking for errors and editing the records available at the estates as outlined in the draft report (Leaker, 1982). This data were analysed using the computer package 'EVENTS' and the results are illustrated taking one of the above six estates, namely, Rayigam Estate in Ingiriya as an example.

The statistical methods used in the study can be applied for 5-day, 7-day, 10-day or Monthly totals, as are the most commonly used periods for grouping data (Stern *et al*, 1982), but are calculated here in 7-day intervals as most cultural operations of rubber growing vary in terms of weeks.

The ' Rains '

For a statistical study of the rainfall regime, definitions of "the weather" have to be specified clearly and unambiguously. The first, concerning this study is the classification of the state of the day, which is either ' wet ' or ' dry '. Though the threshold value for defining a ' wet ' or ' rainy ' day could be set at the smallest measureable quantity, usually 0·1 mm as used by Stern *et al* (1982), the value of such negligible amounts to the rubber tree is questionable. A lower limit of 9 mm has been chosen to define a rainy day and amounts less than this are taken as ' dry '. The amount of rain within a given period, and the probability of occurrence of a given amount of rain within a period, could be calculated directly from the data using weekly totals (Fig. 1a), and percentage points which are computed by arranging the rainfall totals for the period of interest (Fig. 1b), respectively.

The start of rains

The criterion for identification of the start of the ' rainy season ' is fairly complicated due to the irregular pattern of rainfall. Davy *et al* (1976), Kowal & Knabe (1972) and Benoit (1977) have all attempted to define this event for particular conditions, all of which are summarized by Stern *et al* (1982) as a general condition comprising of 3 components. Using this and after some experimentation with Rayigam data, the start of the rains for this estate was found to be best defined as ' The first wet day after the 1st of April with a 7-day total rainfall of at least 105 mm, with at least 5 of the 7 days being wet, and with no dry spell of 3 or more in the next 5 days following this event '. For the northeast monsoon the earliest date was set at 1st September. Fig. 2 shows the start of the rains as a cumulative probability plot, where for instance the probability of the rainy season having started by the 1st week of May is 0·5.

End of rains

This is an even more complicated phenomenon to define precisely because of the uneven distribution of the rainfall in tropical countries like Sri Lanka. Many studies have used threshold values by defining water balance equations to isolate this event (Walter, 1967 ; Gramzow & Henry, 1972). The definition used for the end of the rains for Rayigam Estate was ' The 1st dry day after the 1st of July with a 20-day total rainfall of less than 145 mm '. The earliest end date for the northeast monsoon was set at the 15 of October. Figure 2 also shows the cumulative probability of the end of the rains for Rayigam Estate. For instance it can be seen from this that in 50 percent of the years, the south-west monsoon would have terminated by the 2nd week of July. It is also possible to estimate the length of the rainy season for each year, from these definitions and go on to predict this length for any year given a conditional start date (Stern *et al*, 1982).

Risk of dry spells

The probability of a day or a group of days within a specified period being dry is of interest from many different aspects of rubber cultivation and hence warrants separate

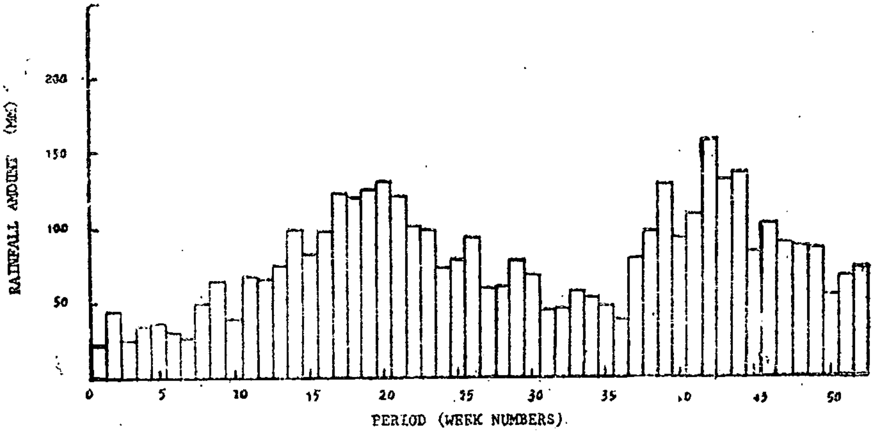


FIG. 1 a. MEAN WEEKLY RAINFALL AT RAYIGAM ESTATE, INGIRIYA.

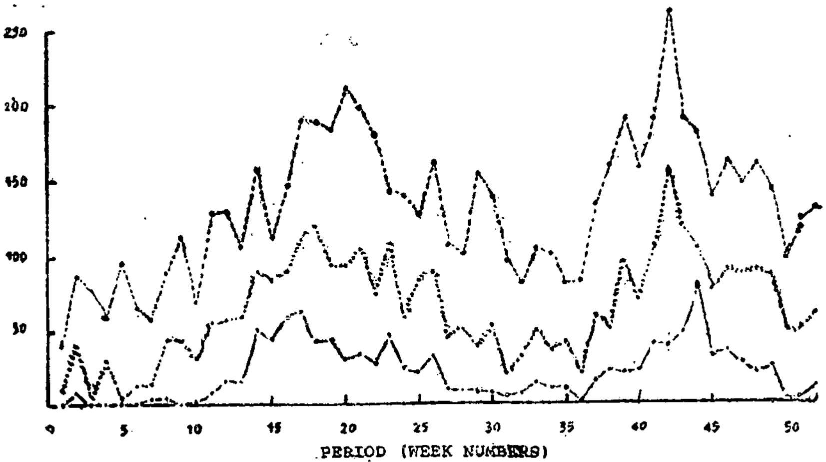


Fig. 1 b. Percentiles of weekly rainfall at Rayigam

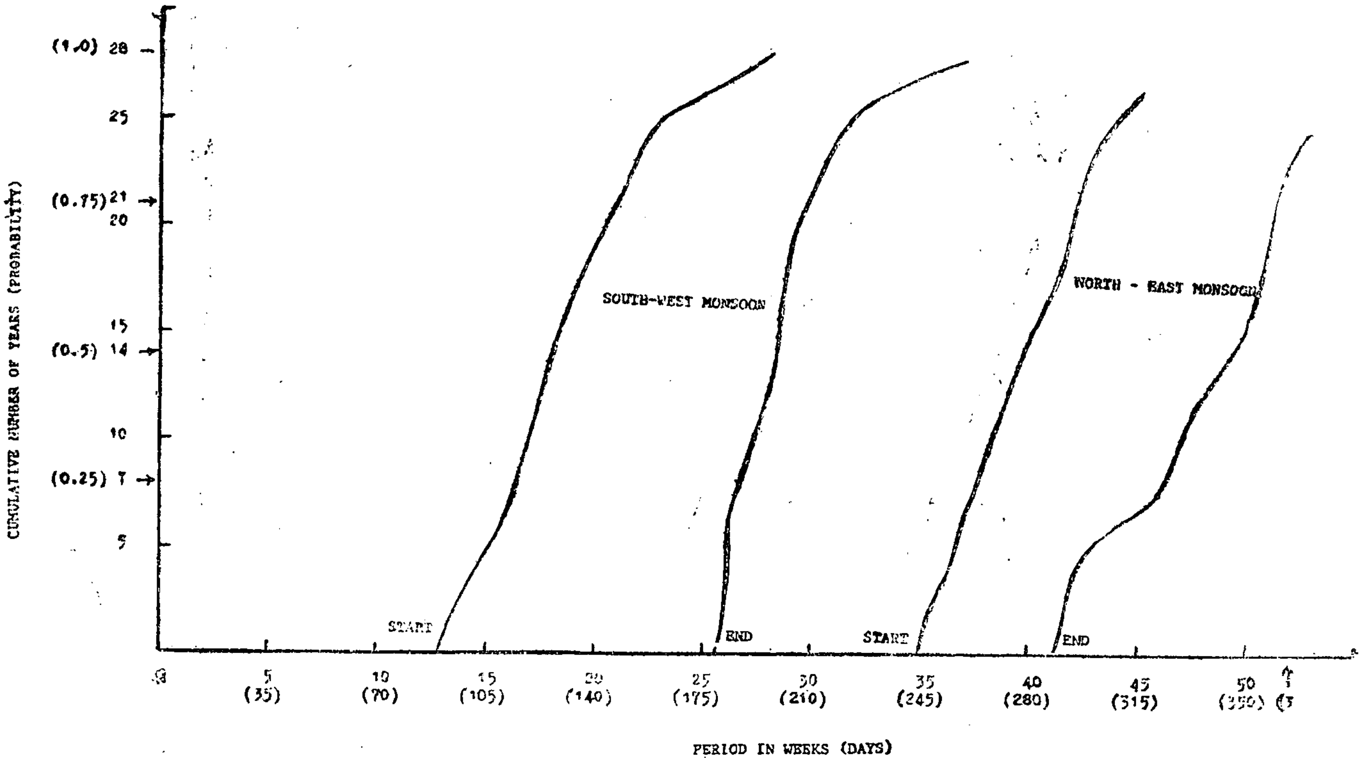


Fig. 2. The start and end of rains at Rayigam

consideration. A low risk of a dry spell having more than a specified number of consecutive dry days is of interest for the success of planting a crop, while a high probability favours operations of burning and tapping. The probabilities of having 7 or more and 14 or more dry days in 30-day periods starting at weekly intervals for Rayigam are shown in Fig. 3. These were calculated directly as the proportion of all years which had a dry spell of that length or greater in the relevant period. From this it can be seen for instance that February has a dry spell of at least 2 weeks with a probability of over 0·6.

Cultural operations

Since the main aim of this paper is to present an agriculturally useful statistical analysis to form a 'crop-calendar', it is necessary to find the effect of the rainfall regime on the cultural operations of rubber growing. The operations considered in this study are clearing, burning, holing, planting, fertilizing and spraying for control of diseases ; the latter three of which may be considered 'critical operations' owing to their significance in improving productivity. In the calculation of optimum periods for carrying out the above mentioned operations, consideration has been given to the fact that the presently recommended dates had been worked out through long experience. Hence the study has been restricted to a 2 — 3 month period about the recommended dates for the various operations. Figure 4 shows dates recommended by the RRISL for these various cultural operations.

Clearing

The operation of clearing, usually carried out in the months of August and September, needs a moist soil for easy removal of roots and hence occurrence of light showers would not affect this operation. The ideal conditions, both from the point of view of sufficient rains and the risk of dry spells can be seen to occur during the period from the 4th week of July to the 1st week of September (Fig. 5a).

Burning

This operation is favoured by dry conditions to enable the roots to be burnt completely and is usually done during February and March. Figure 5a shows that for Rayigam Estate the best time for this operation is between the 1st and last weeks in February where the probability of a dry spell of 2 or more weeks is over 0·6.

Holing

Holing which generally follows immediately after burning also needs moist soil conditions to make digging possible and hence is recommended for late March by which time scattered showers are expected to have set in. The Figure 5a shows a steadily declining dry spell length probability and weekly rainfall of around 70 mm after the 2nd week of March and hence the last 3 weeks of March can be identified for this operation.

Planting

By far the most important and critical operation in rubber cultivation is planting. The viability of a plantation rests on the stand of rubber available for tapping over a

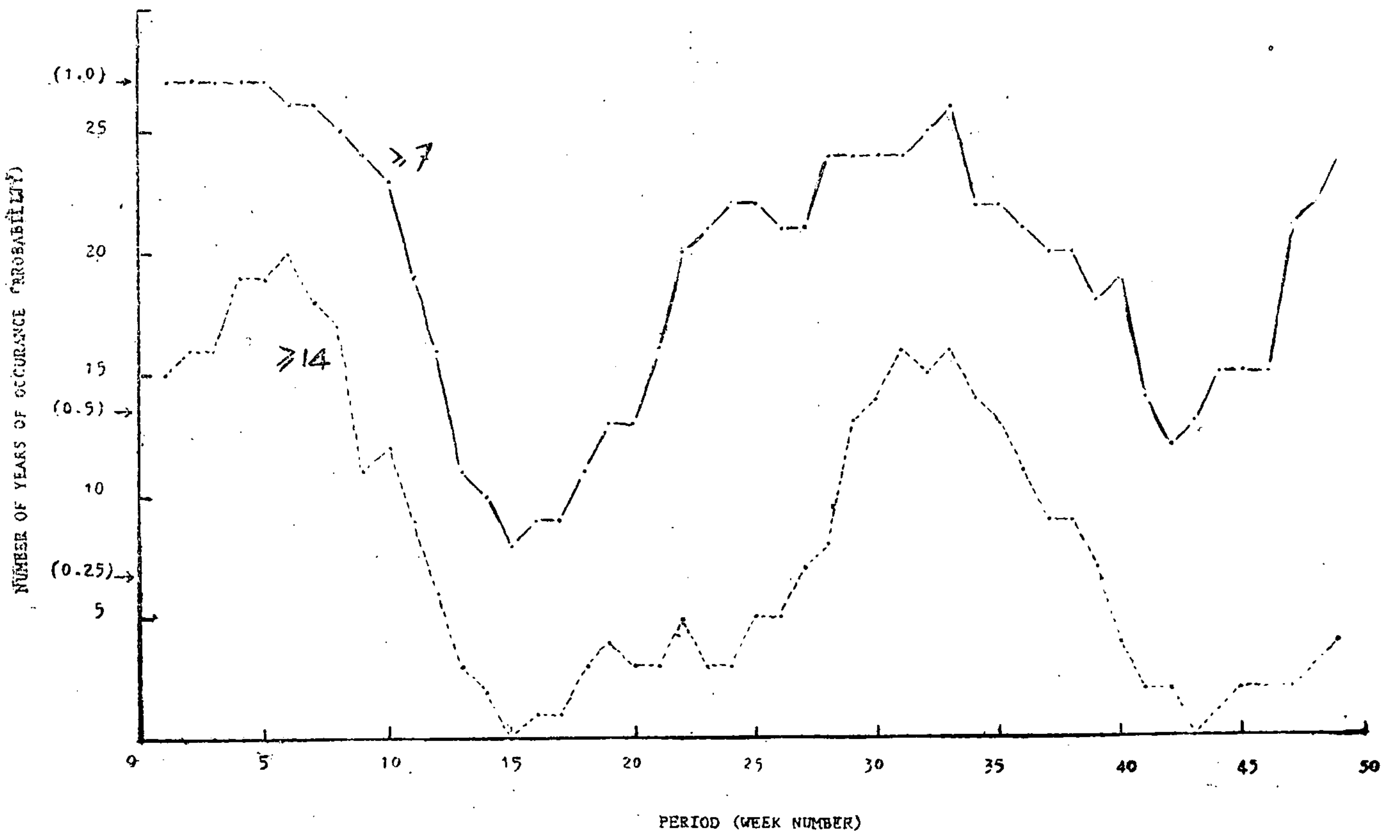


Fig. 3. The probabilities of 7 or more and 14 or more consecutive dry days at Rayigam.

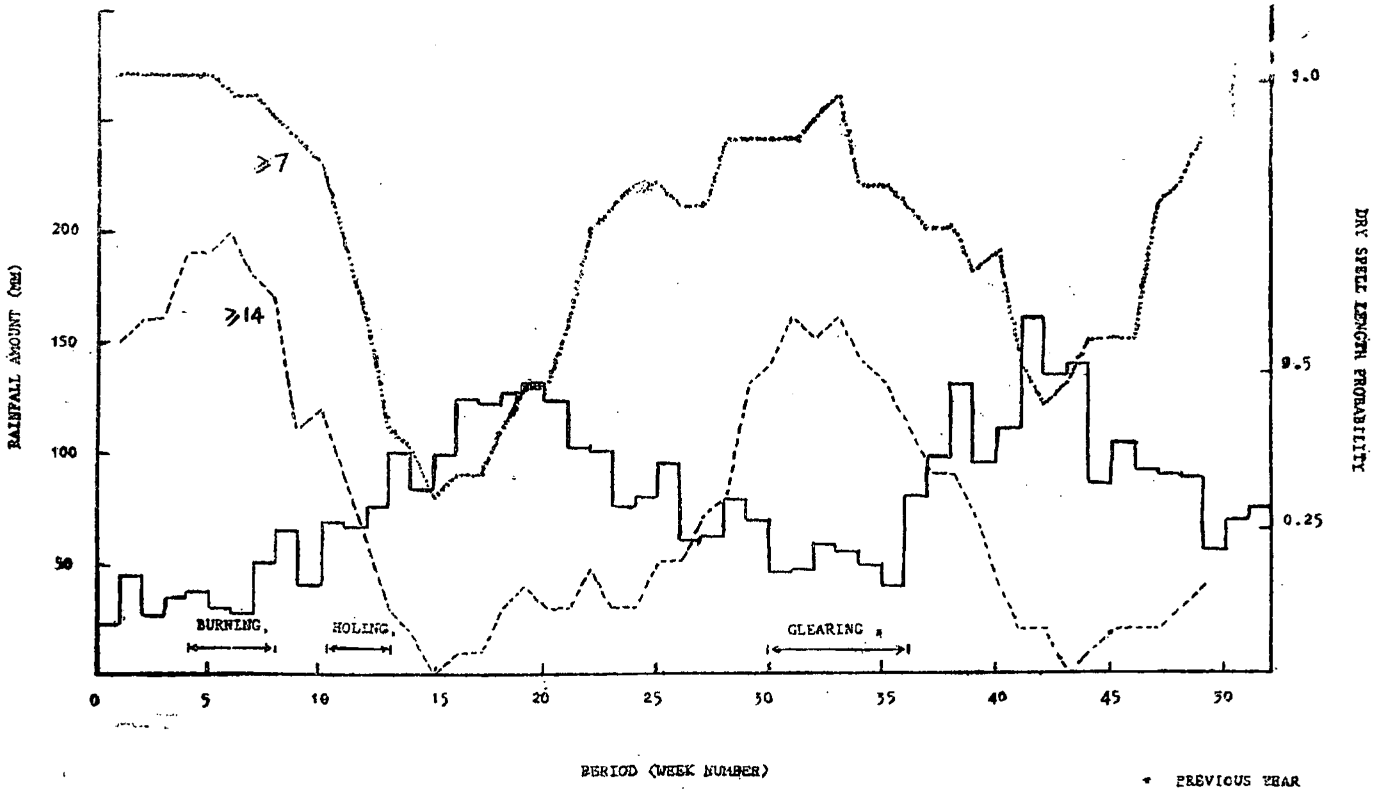


Fig. 4 a. Dates for clearing, burning and rolling for planting rubber at Rayigam.

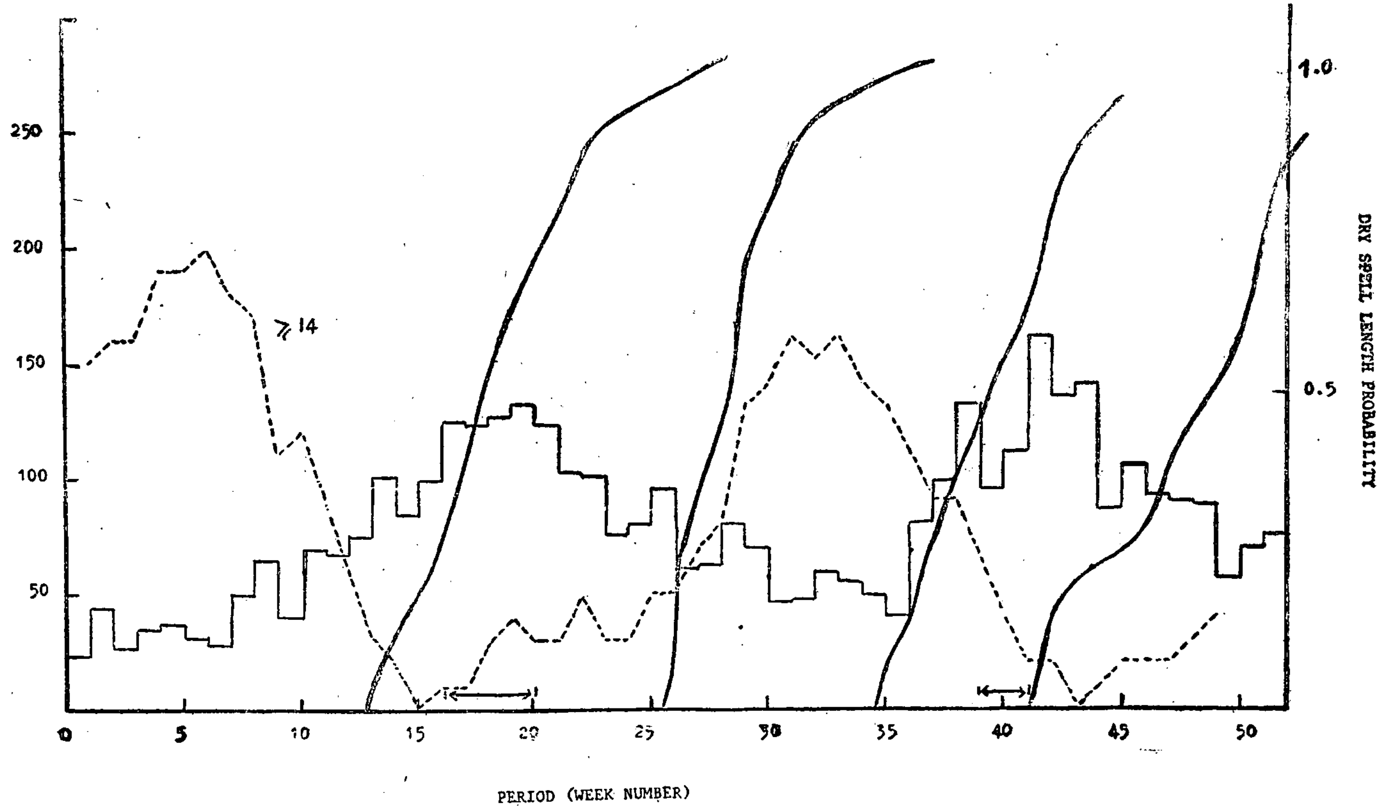


Fig. 4 b. Dates for planting rubber at Rayigam.

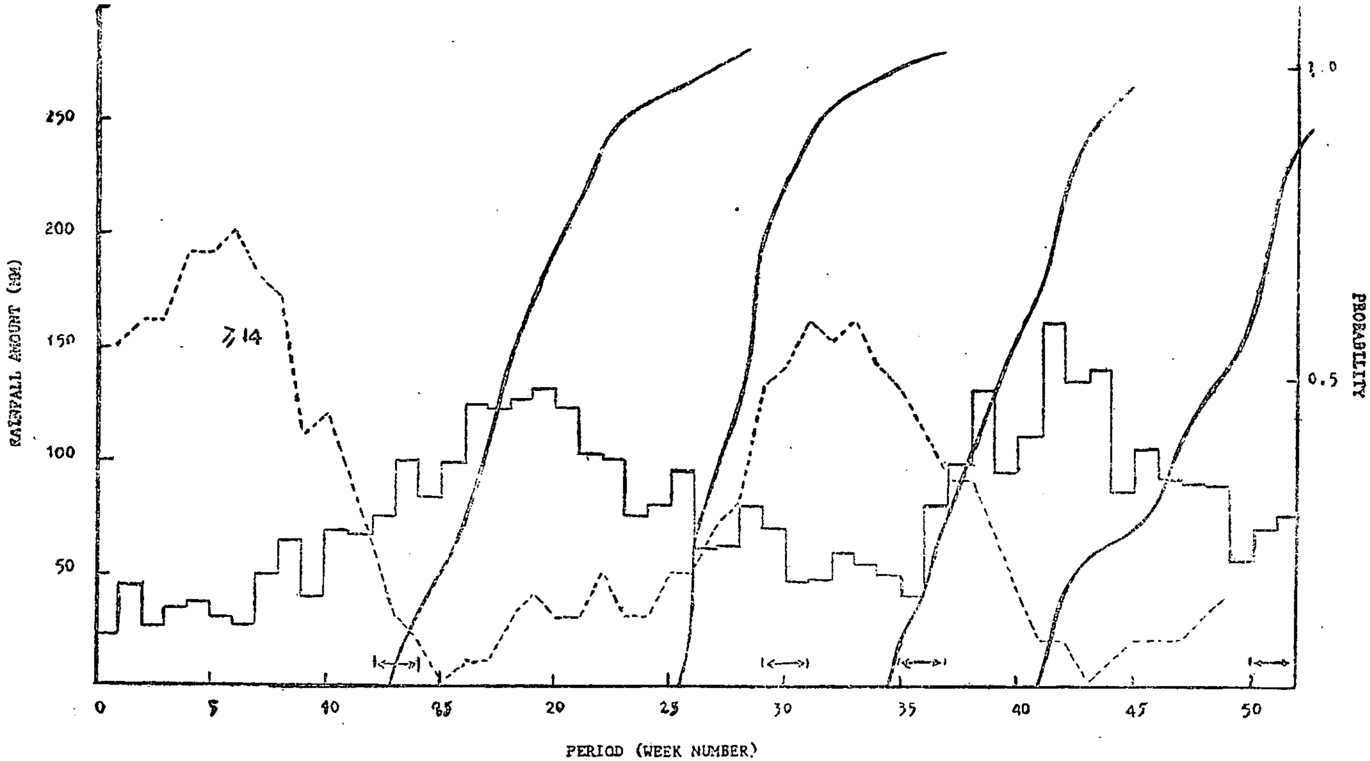


Fig. 4 c. Dates for fertilizer application to rubber at Rayigam.

period of about 25 years. Therefore, it is essential to properly time the planting operations, to provide the budded stumps with the maximum moisture requirements they need for as long a period as possible ; it is only then that a return for the investment on it in its 33-year life cycle can be expected. Since rainfall is available at no cost, unlike major irrigation schemes, it is vital that it is used to the optimum by planting at the correct time. It can be seen that in 50 percent of the years the start of the rains, as defined for Rayigam Estate, have started by the 1st week (8th) of May (Fig. 2) and this should be a suitable and 'safe' time to start planting. However, a closer look at the dry spell probabilities shows that a minimum is reached by mid-April and hence that the risk we take by planting in late April is very small (Fig. 3) and in terms of time, well worth taking since we gain at least 2 weeks in the rainy season. The 4th week of April (25th), therefore is a suitable date for planting rubber at Rayigam Estate as it has both a 2 week dry spell risk of less than 0·1 and probability of start of rains of over 0·35 (Fig. 5b). Planting during the north-east monsoon too could be carried out, though with a less regular distribution of rain as seen by the sudden depressions in the weekly totals (Fig. 1a), and at a higher risk of long dry spells. These factors mean that the planting time during this period is very critical to the successful establishment of the plants. Hence, if there is a choice between the two monsoon periods for carrying out this critical operation, the south-west (SW) monsoon period provides less risk and should be preferred over the north-east (NE). This also makes it possible to fill in the vacancies of the plants that failed to survive the SW monsoon, in the NE monsoon of the same year. The higher risk of occurrence of dry spells during the NE monsoon could be justified financially this way because of the lower capital incurred in a 'in filling' programme. The supply of vacancies therefore could be carried out during the first 2 weeks of October (Fig. 5b).

Fertilizer application

This is still another operation which requires a moist soil but not heavy rains. For this reason the recommended times of application are spread out over the year to make use of the various short wet periods. The obvious dates under these circumstances would be shortly before and after the heavy monsoon rains. Besides this, the early part of the year (February and March), as well as the period in between the monsoons (August and September), too, often have sufficient wet periods signalling the inter-monsoonal rains, to facilitate further applications of fertilizer. For Rayigam Estate four ideal times for applying fertilizer could be identified during the following periods :

Period	Weekly RF (mm)	2 Wk Dry Spell Length Prob.	Probability of Start/End
1. 4th week March-1st week April	80	0·4*	0·1 (S)
2. 4th week July—1st week August	45	0·5	0·1 (E)
3. 1st and 2nd week September	85	0·4	0·1 (S)
4. 3rd and 4th week December	70	0·5	0·8 (E)

* 1 wk dry spell probability. S = Start ; E = End.

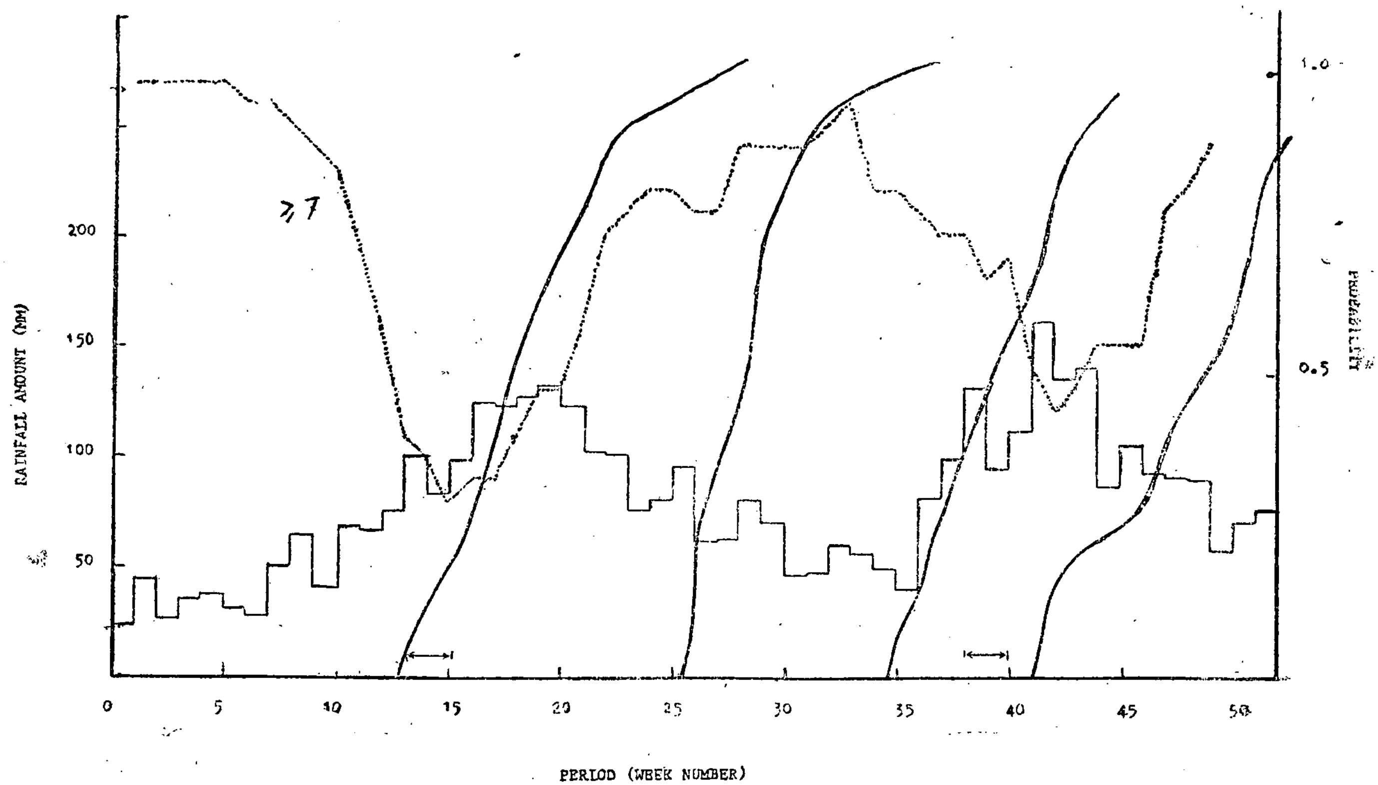


Fig. 4 d. Dates for spraying to control diseases of rubber at Rayigam.

Disease control

This operation has been included in the critical list because of its great influence over the final yield and consequently on the corresponding loss or gain on investment. Most of the diseases of economic importance to the rubber tree thrive in moist weather or during heavy rainfall periods. The diseases that are favoured by heavy rains include leaf diseases *Phytophthora* and *Colletotrichum* and root diseases such as the white root disease. The conditions for disease spread being such, spraying to control disease, has to be carried out shortly before the heavy monsoon starts. There should be no heavy rains during spraying as this will help to wash away the fungicide before it is able to kill off the inoculum. The ideal period for this operation would then be a dry spell within the wet season and for Rayigam Estate the first 2 weeks of April which have a probability of dry spell length of 7 days or more of greater than 0·4 and the last week of September—1st week of October which has a probability of dry spell of 7 days or more of approximately 0·6, seem to best fit this condition (Fig. 5d).

Apart from these operations two other factors of interest could be estimated by the results of this study, though the exact computation is outside its scope. There are :—

1. The estimation of latex yield for each month of the year so as to set realistic targets.
2. The estimation of the 'wintering' period and its length which influences various aspects of plant growth, hence also the final yield.

The former may be done by estimating the number of dry days or tapping days for the month under consideration, and extending it to a study of the relationship between rainfall and yield, which is the subject of another paper by Gibb *et al* (1984b). The latter could be attempted by estimating the time taken for wintering, conditional on a given amount or probability of rainfall, as earlier studies have indicated a possible link between the state of the weather and the length of the wintering period ; it being longer under wet conditions, comparatively quicker in dry weather (Liyanage,1976). As in the case of the cultural operations this study too could be restricted to the February—March period, which is the normal time for its occurrence.

CONCLUSION

It should be noted that this study has been done solely using daily rainfall records and hence may be thought to have stepped outside its scope in attempting to form a crop calendar, especially in the estimating of dates for the 'critical' operations. A more comprehensive study will have to take into account many other climatic and physiological parameters and hence will involve the collection of data such as temperature, times of rain, soil moisture, humidity, evaporation and transpiration, which are not likely to be recorded in most estates. What is considered significant in this study is the fact that every estate that has 20—30 years of rainfall data can work out its own Crop-Calendar without any changes to the method outlined in this paper. Therefore, though the study may be restricted in its accuracy by its focus on rainfall data alone, it uses the available data recorded in estates to the full, and in that sense is intended to be of use to the Managers of Sri Lankan rubber estates.

REFERENCES

ARCHER, D. R. (1981). Rainfall sequences in Northern Malawi. *Weather* **36**, 2—9.

BENOIT, P. (1977). The start of the growing season in Northern Nigeria. *Agric. Met.* **18**, 91 — 99.

DAVY, E. G., MATTEI, F. AND SOLOMON, S. I. (1976). An evaluation of climate and water resources for development of agriculture in the Sudano-Sahelian zone of West Africa : *Special Environmental Report 9*, WMO, Geneva, Switzerland. WMO — No. 459.

GIBB, ANN., LIYANAGE, A. de S., STERN, R. D. DALE, I. C. AND ABEYSEKERA, S. (1984a). The collection and use of yield and climatic data from rubber estates in Sri Lanka. *Proc. Int. Rub. Conf. Sept. 1984.* (In press)

GIBB, ANN., STERN, R. D., DALE, I. C. AND LIYANAGE, A. de S. (1984b). Studying the relationships between rubber yield and climate. (In press) *Proc. Int. Rub. Conf. Sept. 1984.*

GRAMZOW, R. H. AND HENRY, W. K. (1972). The Rainy pentads of Central America *Jn. App. Met.* **11**, 637 — 642.

KOWAL, J. M. AND KNABE, D. T. (1972). An Agroclimatological Atlas of Northern States of Nigeria. Zaria, Nigeria : Ahmadu Bello University Press.

LEAKER, ANN. (1982). Crop-climatic Project (Draft Report) Northern.

LIYANAGE, A. de S. (1976). Influence of some factors on the pattern of wintering and on the incidence of *Oidium* leaf fall in clone PB 86. *Jl. Rubb. Res. Inst. Sri Lanka*, **53**, 31—38.

STERN, R. D., BENNETT, M. D. AND DALE, I. C. (1982). Analysing daily rainfall measurements to give agronomically useful results. I. Direct methods. *Expl. Agric.* **18**, 223 — 236.

WALTER, M. W. (1967). Length of the rainy season in Nigeria. *Nigerian Geographical Journal* **10**, 123 — 128.

STUDYING THE RELATIONSHIPS BETWEEN RUBBER YIELD AND CLIMATE

ANN GIBB*, R. D. STERN*, I. C. DALE* AND A. de S. LIYANAGE**
(University of Reading, UK, Rubber Research Institute, Sri Lanka**)*

ABSTRACT

Records collected over many years can be used to quantify the relationships thought to exist between crop yields and the weather. The methodology of crop-climate studies is outlined using examples from rubber estates in Sri Lanka. Problems such as the choice of sensible variables in multiple regression show the value of using daily data rather than aggregated monthly totals.

INTRODUCTION

Rubber production depends on good management practices and on factors mostly related to the weather, over which the planter has no control. We therefore need to understand more about the effects of the weather on rubber yields, before we can assess the value of modifying management practices. This is a difficult problem, partly because management is itself influenced by the weather, and because other important factors, such as disease incidence, are also influenced by both management and the weather.

In this paper we review briefly the different approaches that are used to study crop-weather relationships, and then describe the methods being used for the data collected at the Rubber Research Institute in Sri Lanka.

Summary of research into crop-weather relations

Statistical studies of crop yields became popular with the advent of electronic computers, which removed the constraint imposed by the necessarily large volume of computation. There has also been considerable research into the physiology of plant growth. Although these and other types of studies have the common goal of quantifying crop-weather relations, both the specific aims and the analytical methods used differ greatly. Table 1 illustrates these differences using three levels of detail at which current research into crop-weather relationships is conducted.

There are several points to note from Table 1.

(a) The control over factors influencing crop production ranges from total control through to no control.

(b) The source from which information is obtained ranges from a single leaf to an estate or district.

(c) The time period over which information is collected ranges from a few hours to more than 30 years.

(d) The models developed change from largely deterministic models of plant processes ('process-based' models) to empirical, statistical models.

Table 1

Level of study	Laboratory studies experimental)	Field studies (experimental)	Observational studies (non-experimental)
Aims	To examine specific plant processes	(a) To study crop growth in partially-controlled environments (b) To identify the 'best' varieties	To study observed crop yields with respect to the weather
Types of data involved	Measurements collected over a very short time (*e.g.* hourly) from laboratory experiments	(a) Crop-growth measurements over a time period shorter than the growing season *e.g.* daily. (b) Yield data collected from a sequence of trials over time (usually for less than 5 years) and space	Historical data. Yield records kept to monitor crop performance
Analytical methods	Sophisticated biomathematical models.	Growth rate models Genotype-environment analysis.	Statistical models using regression analysis

This shows that there is a considerable range in the types of study, and also that the models are very different in many respects. Most studies are either process-based or empirical, but we feel there is considerable scope for intermediate models. To make this clear, we will outline the two types of model before developing one for the rubber data.

Process-based models

Process-based models have been developed mainly for annual crops. They are also known as physical, physiological, simulation or dynamic models. The aim is to represent the operation of the 'system' (*e.g.* a plant or a field) by a set of deterministic equations. These describe the various plant processes and the way they contribute to the system. As far as possible, each component of the model is investigated and quantified at a detailed, experimental level. The components are then put together to simulate yield production. The essential aspect is that these models are based on an understanding of the physical and physiological processes, and how they are inter-related.

For example, a model of a cereal crop would simulate the characteristics at each growth stage which contribute to the final yield. These are likely to include the following : emergence dates, number, size, appearance and senescence of leaves ; leaf area indices ; potential evaporation ; partitioning of dry matter and kernel production.

Empirical or statistical models

These are also known as observational or black-box models. They do not attempt to understand the physical processes governing the operation of the system but relate crop-yield directly to the observed weather variables. The techniques of multiple regression are usually used to examine these relationships.

Many models of this type have been developed, for both temperate and tropical crops. However, many agricultural scientists have considerable reservations about their value. This scepticism stems from doubts about the ability of such models to reveal results of general significance for complex crop-weather relationships. Their reservations seem justified since few models have been successful in revealing the important weather variables and even fewer have been of much practical use.

Some of the shortcomings are due to the inherent limitations of the empirical approach. Firstly, the models lack general applicability, since the parameters used are usually location-specific. Care must be taken when extrapolating beyond the range of the data used to fit the model. Secondly, with a limited number of years of crop data available, several models are likely to be equally consistent with the data. Thus many models can account for the majority of yield variation but they do not explain it.

Nevertheless, when conducted properly the statistical approach has much to offer. It has succeeded in suggesting priorities for applied research, and in confirming experimentally derived knowledge. The more successful models have involved greater care in data collection at the correct level of detail, critical application of the necessary statistical techniques, and weather variables which are directly relevant to crop growth, such as evapotranspiration or soil moisture.

Thus, the 'intermediate' type of model is a statistical model in which the weather variables are derived from an understanding of the physical processes. It is this type of model we intend to develop for the rubber data.

Studying the relationship between rubber and climate

The reliable, daily crop records available at an estate level for many years enable us to investigate the potential of the statistical models. We began by developing a methodology for analysing the rubber data. This is illustrated using one estate, Dartonfield.

In most such statistical studies regression analysis is used. The aim is to relate the fluctuations in yield (y_i) to the fluctuations in weather (x_i). The regression model usually takes the following form :—

$$y_i = a + b_1.x_{1i} + b_2.x_{2i} + b_3x_{3i} \ldots + ei$$

y_i, is the yield (the dependent variable) whose variation we are trying to explain.

x_{1i}, x_{2i}, x_{3i} ... are the weather variables. They are called independent or explanatory variables since they are explaining the variation in yield.

a, b_1, b_2, b_3 ... are the parameters which quantify the relationship.

e_i is the residual, or the part of yield variation we can't explain.

This model does not mean that the weather variable (x_{11}, x_{21} etc.) make the yield figure, y_i, but that changes in one or some of the x_i's result in proportional changes in the yield.

Many studies, after having collected the data, proceed with a regression analysis almost immediately. With the rubber data, we found it necessary to consider two preliminary steps, before proceeding to a regression analysis.

1. Choice of the dependent variable. If we want to explain variations in yield by weather then we must ensure our yield figure is a valid reflection of the weather effects by removing, as far as possible, any other known effects (*e.g.* by including these effects as independent variables).

2. Choice of the independent variables. We have noted earlier that rainfall is an important variable in rubber production, but is it the rainfall amounts that we wish to relate to rubber yields, or some variable derived from the rainfall amounts ?

Choice of the dependent variable

For Dartonfield we have daily tapping records for 19 years, *i.e.* 365 × 19 yield values. We start by looking at the raw data (Fig. 1).

There is a seasonal pattern, but there is a lot of noise in the data and it is difficult to detect much else. So daily data may be too detailed. At the other extreme, yearly totals give 19 values for yield (Fig. 2).

This gives a clear picture of total production over the years but by aggregating to this level we have lost a lot of information. At this stage monthly totals would seem a sensible compromise between the two extremes of daily and yearly totals.

However, if we look again at the daily data (Fig. 1), we can see that a monthly total is affected by

(i) the number of days when little or no rubber was tapped mainly because of rain interference.

(ii) the number of large peaks due to double tapping.

(iii) the amount of latex recovered on normal tapping days.

Thus, it would seem unwise to use a monthly total and more appropriate to study the amount of rubber tapped on each of these three types of days, since they make up the monthly total. We can summarise the way they contribute to a monthly total in the following way.

Monthly total	=	Average yield on normal tapping days in a month (component 1)	×	Number of tapping days in the month (component 2)
	+	Yield on double-tapping days (component 3)	×	Number of double-tapping days in the month (component 4)
	+	Small amounts of rubber collected before rain interference (component 5)		

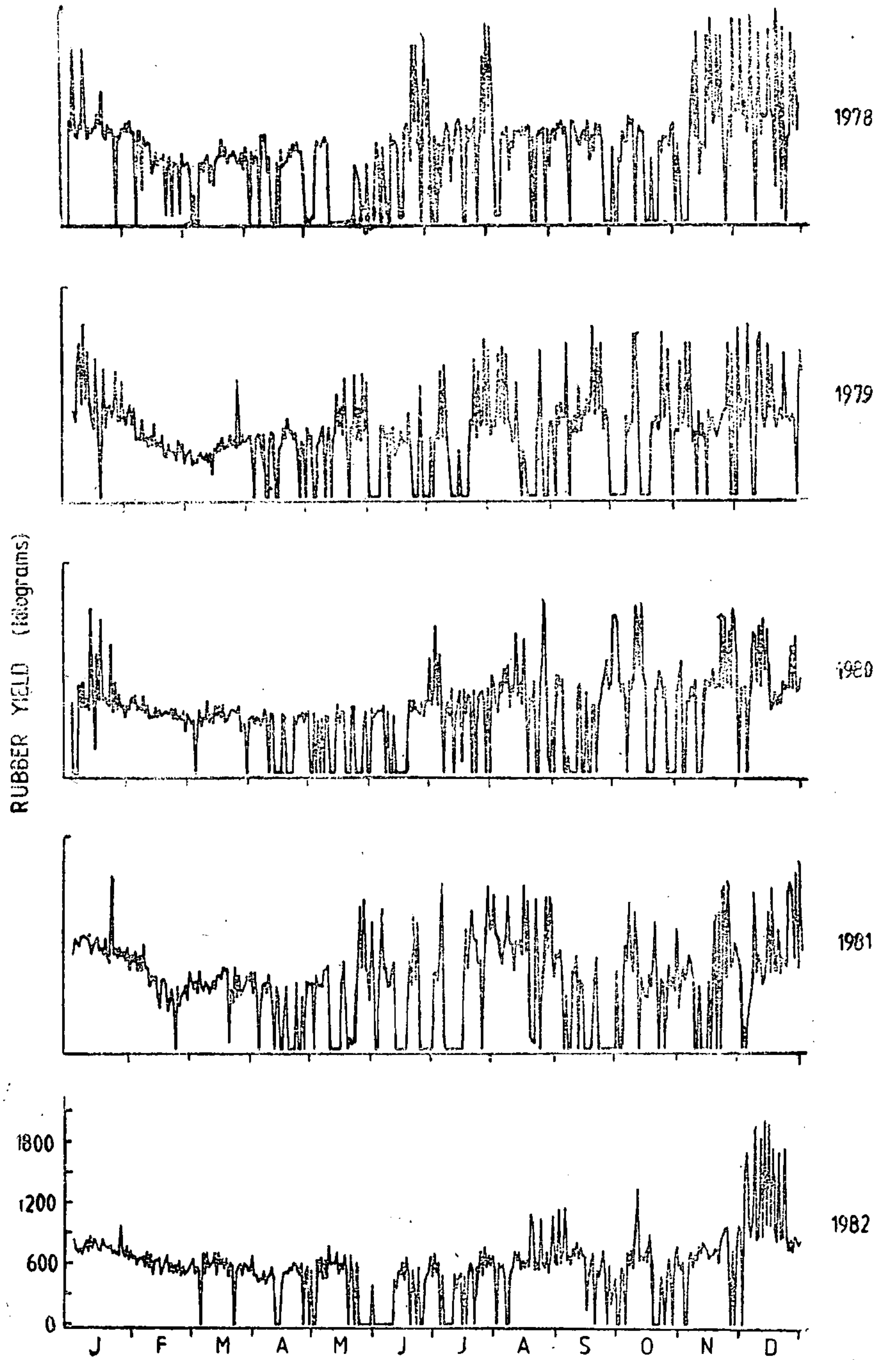


Fig. 1. Daily rubber yields at Dartonfield, Agalawatta, showing:
(a) troughs—days when rain interfered with tapping ;
(b) peaks—days on which double-tapping took place ;
(c) days when normal tapping was done.

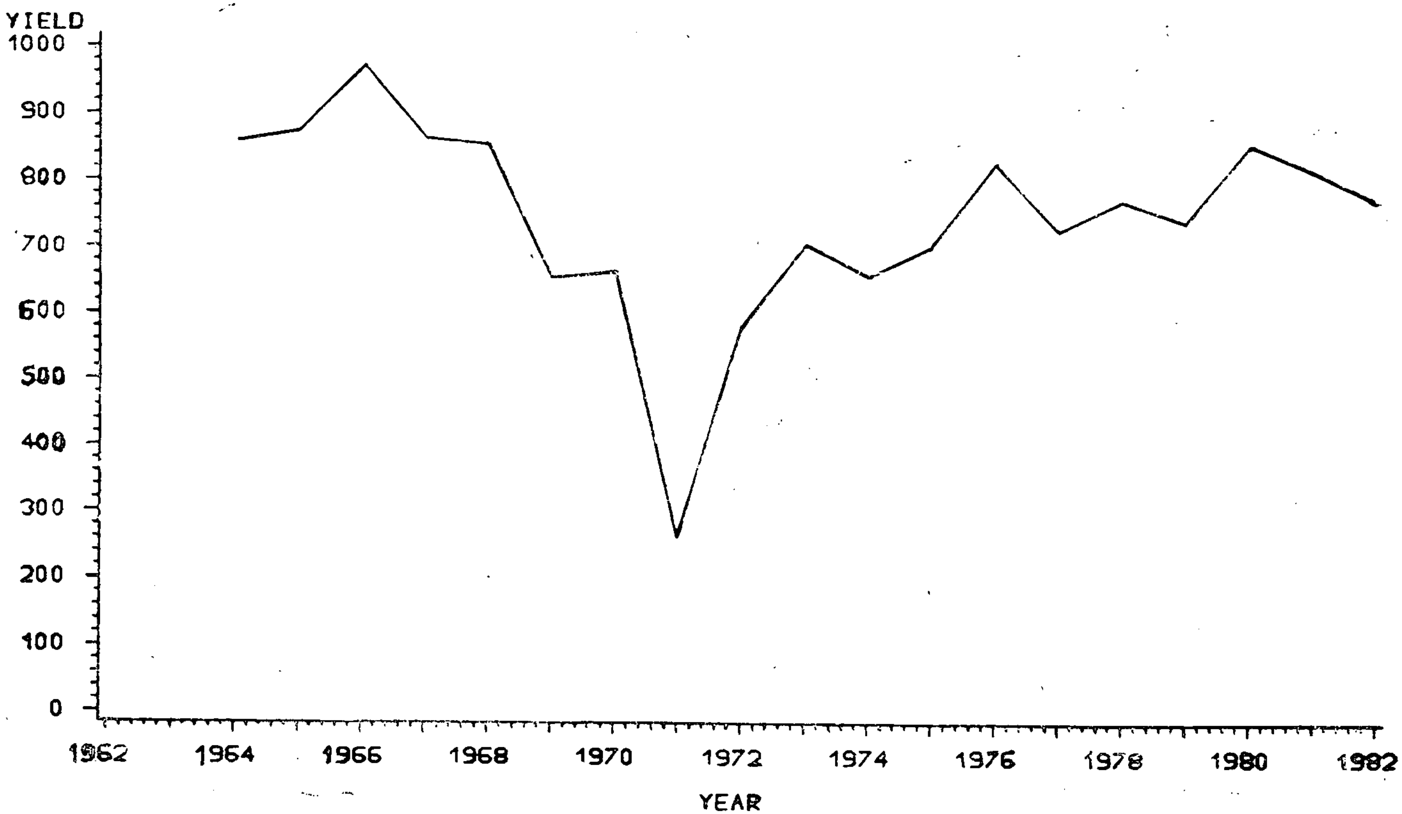


Fig. 2. Annual total yields at Dartonfield from 1964 to 1982.

To be able to predict rubber production we must look in detail at each component.

Component 1 — yielding capacity

We like to think of the amount of rubber tapped on a normal tapping day as the 'yielding capacity' of the estate.

The yielding capacity for Dartonfield was calculated by comparing the daily yield figures with the detailed tapping records. These indicate whether double-tapping, late tapping or normal tapping took place on a particular day, and whether rain interfered with the day's tapping. The yields recorded on normal tapping days are used to give an indication of the yielding capacity of the estate. Fig. 3 shows the yielding capacity at Dartonfield in 1980.

It is this component of yield that is our dependent variable, which we shall try to explain in terms of weather and cultural practices.

Component 2 — number of tapping days

Alternatively we could use the number of tapping days lost, which is directly attributable to rainfall. We can compare directly the daily rainfall and daily yields to estimate the number of tapping days lost.

Component 3 — number of double-tapping days

This is a consequence of the estate manager's policies, so this component is to some extent dependent on cultural practice. However it is also dependent on the state of the trees (when the trees are refoliating, the yield potential is low and most planters do not double tap) and on whether there is a need to meet a production target.

Component 4 — yield recovered by double-tapping

This depends on the yield capacity of the trees, which itself varies through the seasonal cycle. The amount recovered can be expressed as a ratio of the yielding capacity, where this ratio is between one and three.

Component 5 — small amounts

The days when rain interfered with tapping were also recorded on the books at Dartonfield. At this stage of the analysis the first four components seem more important, so we have not considered this component further.

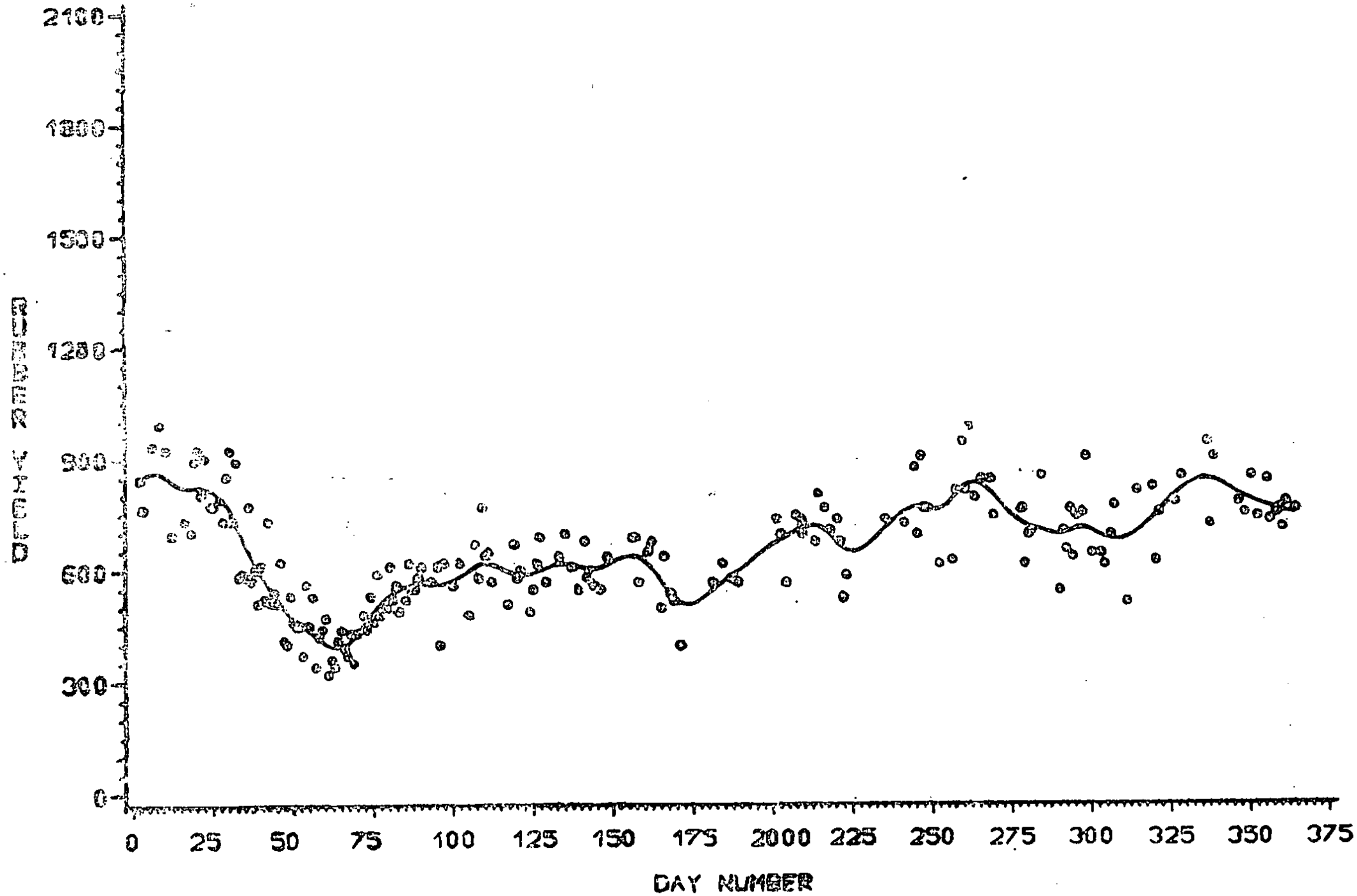


Fig. 3. Yield on normal tapping days at Dartonfield.

Choice of the independent variables

Usually many weather variables are available for use in a multiple regression. For example, raw climatological variables such as rainfall, maximum and minimum temperatures, radiation, wind speed, evaporation or sunshine hours can be considered. Alternatives, such as soil moisture or degree-days, can be derived from the raw data. In addition, quadratic as well as linear terms for each of these factors can be included, if a non-linear relationship between yield and the weather is envisaged.

Exactly which variables to choose is relatively straight forward when a lot is known about the crop-weather relationships. Often little is known, and statistical techniques may be needed to indicate the more important variables. Discussions between statisticians and agriculturalists are essential especially at this stage of a study of this kind. Such collaboration ensures that the statisticians are working with realistic variables, and that the results are agriculturally sensible. We are finding it invaluable to collaborate with planters and with staff at the Rubber Research Institute.

With rubber yields it is clear that rainfall is important but we also need to investigate whether other types of climatic variable are relevant. Monthly maximum, minimum and average temperatures at Dartonfield were examined as potential variables in relation to monthly yield, but nothing notable was found.

Monthly averages of weather variables are often considered plausible factors to relate to monthly yield data. However, monthly averages or totals conceal information about the distribution through the month and the occurrence of any extremes, both of which could be detrimental to rubber production. For example, a month with 250 mm of rainfall would not unduly disturb a planter, but this 250 mm could have fallen on 5 days following a dry spell of 25 days. Using the daily rainfall data we derived more relevant variables, such as the maximum dry spell and the number of rainy days in each month, with initial results improved on those from rainfall averages.

The use of daily rainfall also meant that we could calculate daily soil moisture. We used a simple model with a field capacity based on recent experimental work at the Rubber Research Institute. By the same argument as above, a monthly average may not be the best way to summarise soil moisture. A more realistic variable may be the maximum number of consecutive days that the soil moisture value is below a critical level. This can be interpreted physically as a "stress index". Initial findings with lagged stress indices seem to confirm this (Fig. 5).

Relating the yield to the weather

Only preliminary work has been done so far. Initially monthly yield totals were related to monthly averages of weather data, but the results were no more successful than those obtained by other crop studies using monthly data. Derived weather variables, such as a lagged stress index based on soil moisture, were more rewarding, particularly when the yield capacity data were crudely adjusted to allow for serial correlation. However, this is not conclusive, since the studies were deliberately exploratory, based on only

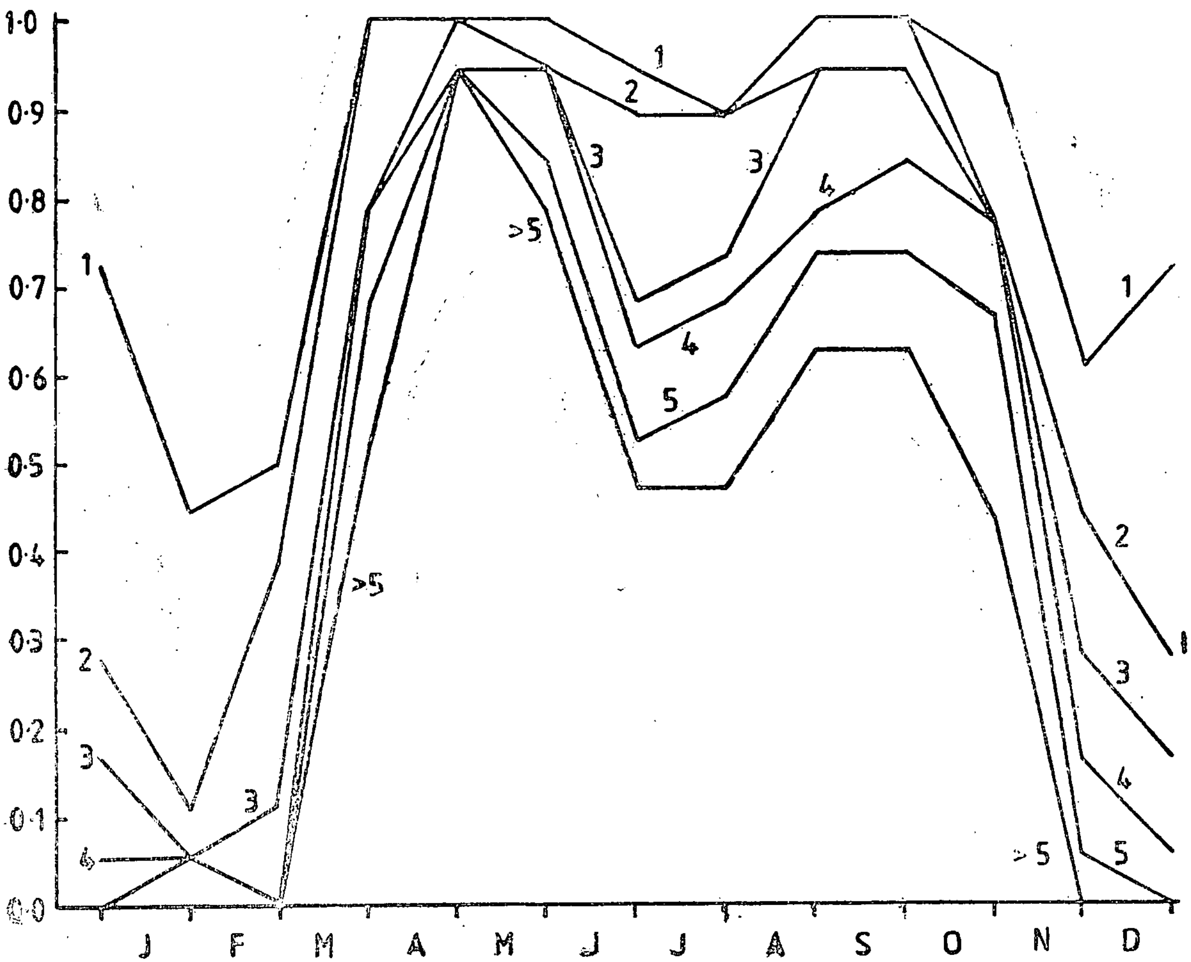


Fig. 4. Probability of losing " n " tapping days in each month, calculated as the proportion of years which lost " n " or more tapping days in each month.

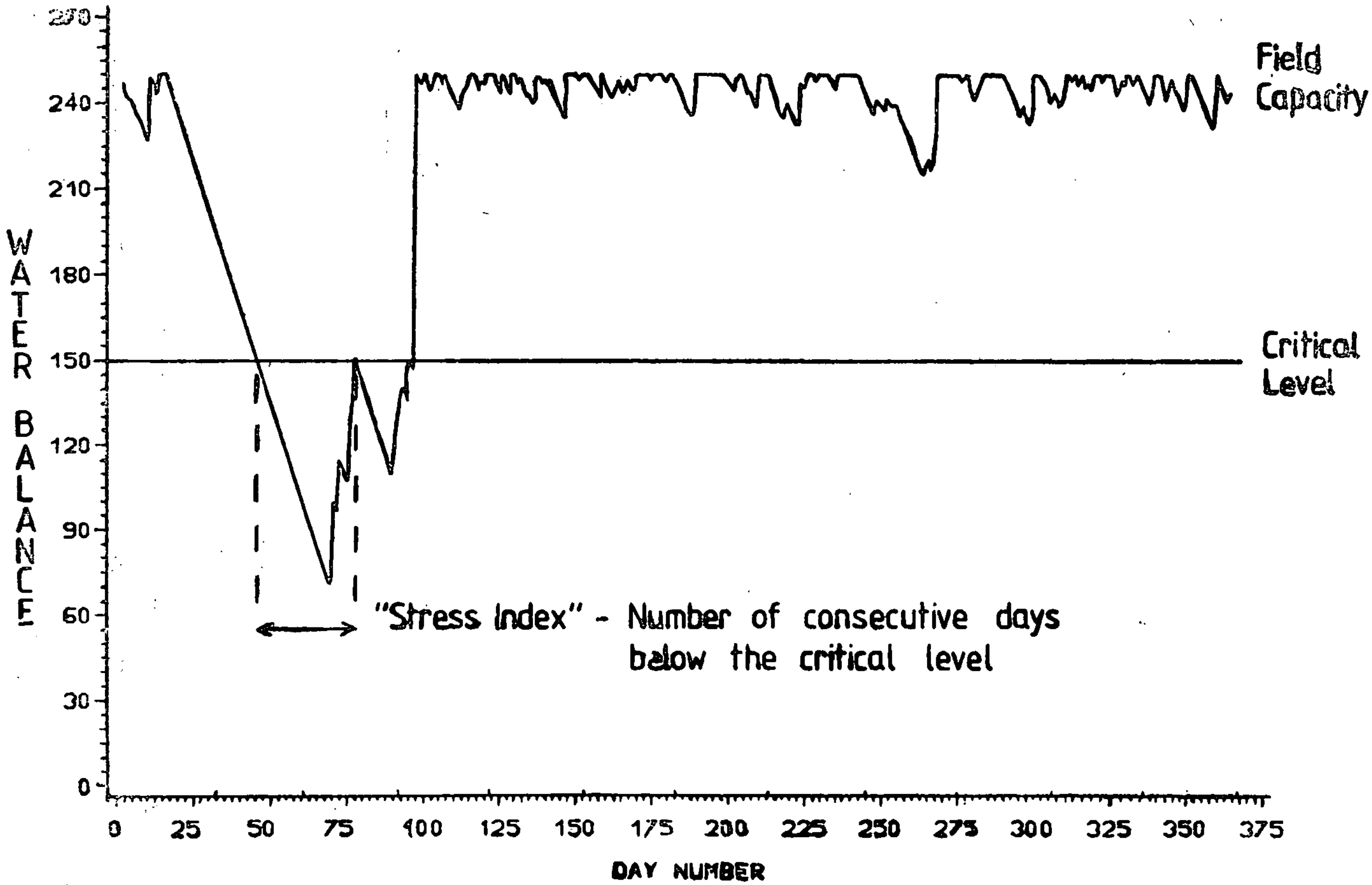


Fig. 5. Daily soil moisture budget for Dartonfield in 1980, calculated from daily rainfall and monthly evaporation.

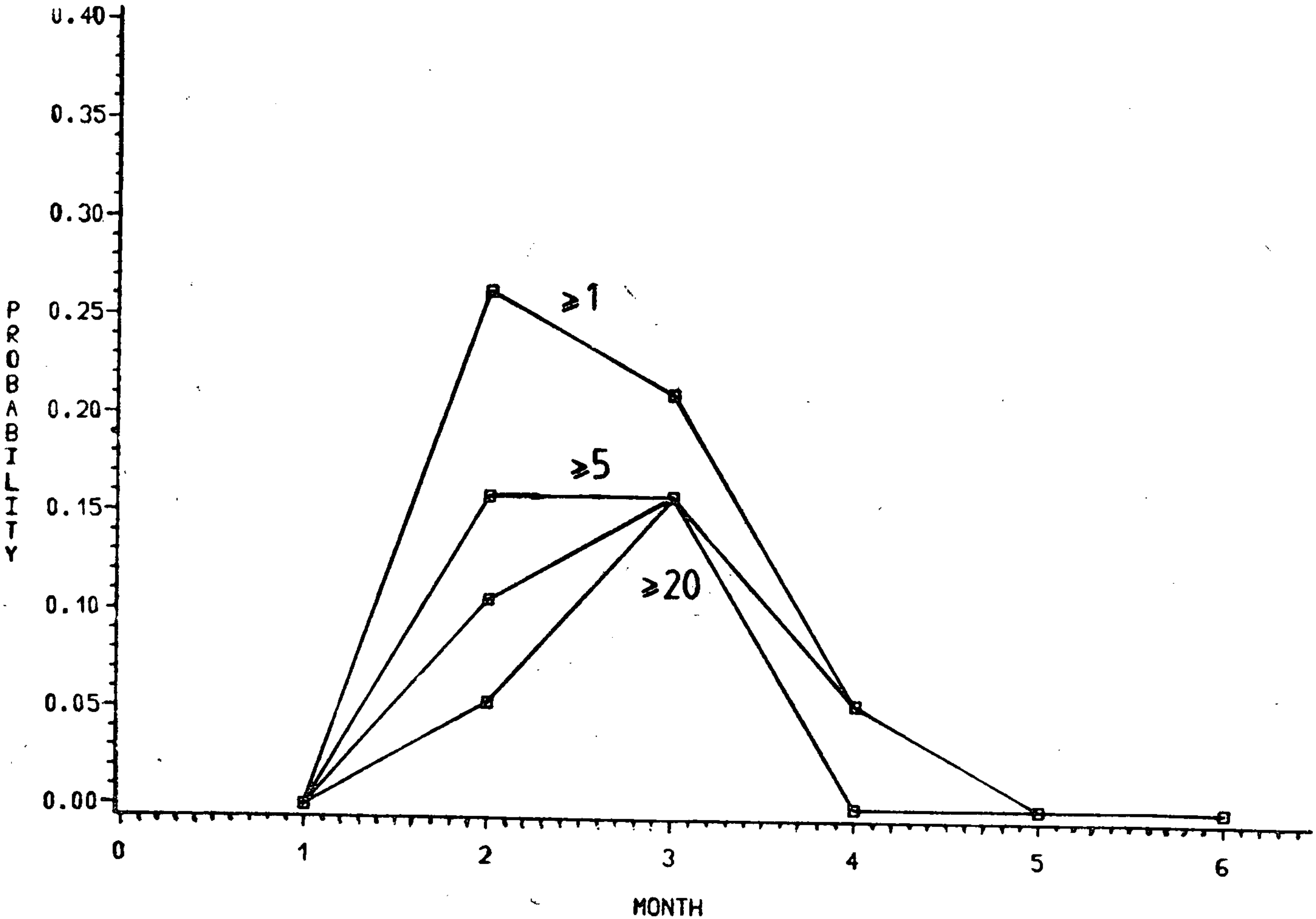


Fig. 6. Probability of 1, 5, 10, 20, or more consecutive days less than the critical level (150 mm).

simple adjustments. Moreover, monthly yield data may not be the best level of aggregation to use. Better results are expected for smaller levels of aggregation, such as 6 or 12 day averages, but this needs more research to understand the complexities arising from an increase in serial auto-correlation in both the yield capacity averages and the lagged variables.

For the second component of rubber yield, the number of tapping days, we have done little work yet but the clear link with daily rainfall means there is considerable scope for useful investigations.

Research is also called for into the other components, particularly the frequency of double-tapping, and the additional quantity of latex recovered. However, until investigations of the first two components are completed, useful work on the others will be restricted.

Extending the work to the data bank

The initial analyses of data from Dartonfield are intended to fulfil several purposes.

(i) They establish a methodology which can be applied to the other sites.

(ii) The availability of data on other variables besides rainfall permits an evaluation of the methodology for sites where only yield and rainfall data are available.

(iii) Discussions with staff at the Institute on the derived independent variables, such as soil moisture, are made possible. We have found these very helpful, also, questions that cannot be answered at present may be linked to some of the experimental research.

Extending the work to the complete data bank will be difficult. The broad strategy is as follows. Initially, separate analyses will be made for those sites with long records. These will enable us to compare the relationships between the climatic variables and yield, and subsequently to assess the extent to which yields can be predicted from climatic records. The results from the individual sites will then be combined. Final products from the work should range from guidance to estate managers on useful ways in which they can present their data, to the construction of maps of the potential yield and its variability.

CONCLUSIONS

Most agricultural research institutes devote disproportionate resources to the collection of new data, as opposed to the analysis of routine records and surveys. Rubber is one of the few examples of crops where detailed long records exist from sites other than research institutes. These papers have demonstrated some of the uses of such data. This collaborative project is designed to establish a methodology for their analyses and, if successful, we hope that a comprehensive analysis of the data bank will then be undertaken.

It is important not to underestimate the complexity of the task that lies ahead. Establishing the methods of analysis for records over the different sets of years for the different estates will produce problems of statistical research and of data management. The care and effort taken in collection and computerisation of the data bank deserves subsequent analyses to be conducted with equal care and effort. Success should encourage staff at estates to keep even more complete records for the next 30 years !

THE 'RUBBER CLIMATE' OF SRI LANKA : OBSERVATIONS ON AN AGROCLIMATIC LAND CLASSIFICATION FOR RUBBER CULTIVATION IN SRI LANKA

By

M. DOMROES
(*Mainz University, W. Germany*)

Rubber plays a major role in the economy of Sri Lanka. It is next to tea and coconuts a " major commercial crop " which is due to its large extent of cultivation (at present around 207,000 ha) and its major export importance (1983 : 11·4% of the island's total export earnings). On the world rubber market, Sri Lanka ranks among the leading producers. According to the type of cultivation, rubber is cultivated both in plantations (around 55% of all rubber lands) and smallholdings. Rubber cultivation mostly takes place in the wet lowlands and mid-country of the Southwest part of Sri Lanka.

The successful cultivation of rubber depends largely on a favourable environment, in particular climatic conditions. It is therefore the aim of this paper to describe the ' rubber climate ' of Sri Lanka, by correlating the general climatic requirements for rubber cultivation with the particular climatic conditions in Sri Lanka. From this viewpoint, the study's final aim is to contribute to an agro-climatic land classification for rubber cultivation in Sri Lanka.

The rubber climate in general can be described as wet-tropical. This overall climatic criterion needs to be clarified. From the viewpoint of *temperature*, high values between 25 and 27°C all-year-round are regarded as most suitable for a high latex production. These values refer to the daily and monthly averages which, therefore, should be rather homogeneous in order to satisfy the high temperature demand of *Hevea*. Latex production shows a significant relationship to the temperature course over the year, in the following way : the larger the range of temperature the lesser the yields, and vice-versa.

For rubber cultivation, also a high supply of *water* from *rainfall* is regarded as a basic agroclimatic criterion. This can be best satisfied by an annual total around 2,500 mm, and least fulfilled by 1,500 mm, but principally rainfall should be evenly distributed round the year. However, there does not seem to exist an upper limit of the annual rainfall total for rubber cultivation. A dry period, in any case, adversely affects rubber cultivation, although it is still uncertain how to define accurately such a dry period. In this direction, soil water storage capacity is of greater importance so that a dry period from the viewpoint of rainfall is not necessarily also a dry period in agroclimatic terms.

Although of minor importance *wind* also represents an agroclimatic index to be considered for rubber cultivation. In particular strong and gusty winds are disadvantageous to rubber trees, since they may cause mechanical damage, such as breaking of branches, defoliation and even uprooting of the rubber tree. Strong winds, however, affect rubber cultivation on a rather smaller scale, mostly in wind-exposed areas.

From an overall view, the optimum conditions for rubber cultivation depend largely upon specific agroclimatic criteria related to temperature and rainfall. It is, however, not only a definite total or amount of both climatic elements, but also their distribution round the year which affect rubber cultivation.

On the basis of generally valid indices for rubber cultivation, an agroclimatic classification of rubber lands in Sri Lanka can be worked out as follows :

Temperature

The requirements of a high annual average between 25 and 27°C are ideally fulfilled all-over the lowlands of Sri Lanka and even include the lower hill country. While the lowlands record a mean annual temperature slightly varying around 27°C, temperature decreases at 0·6°C/100 m, so that an annual average temperature of 25°C roughly coincides with the 300 m — isohyet. As reference stations can be taken Colombo (7 m a.s. l.) and Kandy (477 m a.s. l.) which record a mean annual temperature of 27·0°C and 24·4°C, respectively.

With regard to the requirement of fairly even temperature conditions for rubber cultivation, Sri Lanka again provides most favourable conditions. In no part of the island does the annual temperature range exceed the rather low value of 4·3°C, in most cases, temperature all-year-round just varies between 2 and 3°C. The smallest values of the annual temperature range occur in the Southwestern lowlands where Ratnapura recorded the lowest range for Sri Lanka (namely 1·5°C) while Colombo and Galle recorded 1·8°C each (both are 30 year averages from 1931 to 1960). Reference of the even course of temperature through the year is given by the monthly temperature for Colombo (30 year average from 1931 to 1960).

JAN.	FEB.	MAR.	APR.	MAY	JUN.	JUL.	AUG.	SEP.	OCT.	NOV.	DEC.
26·3	26·5	27·2	27·7	28·0	27·4	27·1	27·2	27·2	26·6	26·3	26·1

A small temperature range is, however, true not only in respect of the annual range, but also of the daily range. The values are in fact larger than the annual ones which is a principal rule for the tropics, but for Sri Lanka the daily temperature range is comparatively small, due to the moderating influence of the surrounding Indian Ocean. Also from this viewpoint, the rubber climate of Sri Lanka is significantly favoured. The mean daily temperature range for Sri Lanka mostly varies between 5 and 10°C only. It can be clearly seen that the daily temperature range increases with increasing altitude a.s.l., and thus the lowest values occur in the lowlands, the highest in the central highlands of Sri Lanka. Slightly differing values also occur in seasonal terms, being mostly caused by rainy or dry weather conditions.

Referring to the temperature conditions as a whole which are required for rubber cultivation, Sri Lanka's thermal-climatic conditions over the Southwestern lowlands ideally coincide with the requirements for rubber. However, in terms of temperature only, all other parts of the lowlands would be favourable to rubber as well.

Rainfall

The high annual total of 2,500 mm and above required for rubber cultivation, occurs in the comparably small Southwestern part of Sri Lanka only. The 2,500 mm — isohyet approximately runs from Panadura on the West coast via Kegalle, Nuwara Eliya, Balangoda and East of Deniyaya to Galle on the Southwest coast, it thus shows that only a small section of the Southwestern lowlands plus the Western slopes of the Central highlands and the Sabaragamuwa hill country receive the appropriate annual rainfall total which offers best growing conditions for *Hevea.* In addition, the rather small area of the Knuckles also gets above 2,500 mm annual rainfall and thus also fulfills the high annual rainfall requirements.

Taking into consideration the minimum amount of annual rainfall (1,500mm)the potential cultivation area for rubber would be widely spread over larger parts of Sri Lanka, covering not only the total Southwest sector (which is commonly understood as the 'Wet Zone' of Sri Lanka), but also the whole central highlands and larger areas of the Central, Eastern and Southeastern lowlands and thus of the so-called 'Dry Zone' of Sri Lanka.

Besides the high annual rainfall total, rubber cultivation also requires an even distribution of rainfall round the year. It is, however, the very nature of the tropical monsoon climate, to which Sri Lanka obviously belongs, that seasonally variable rather than homogeneous rainfall conditions are prevailing. Rainfall distribution over the year, therefore, shows for Sri Lanka a considerable variation, yet principally an alternating wet and dry season occurs, according to the monsoon rhythm. The length of the wet and dry season as well as the total rainfall in each of them varies regionally to a great extent. Evidence of the seasonally alternating type of monsoon rainfall for Sri Lanka is given by rainfall — temperature diagrams for six selected stations in the Wet Zone and Dry Zone (Fig. 1). The diagrams are based on the 'aridity index' of de Martonne/Fauer (1952), monthly rainfall and temperature records are 30 year mean values (from 1931 to 1960). From the diagrams it can be followed that, despite a rather fluctuating distribution of rainfall round the year, the three reference stations of the Wet Zone, namely Watawala, Colombo and Nuwara Eliya, do not show the remarkably large variation of rainfall which is typical of the Dry Zone (see the diagrams for the reference stations Anuradhapura, Ampara and Hambantota). In addition, the Dry Zone stations clearly show a distinct and well established dry period which is at the same time an agroclimatic disadvantage, since perennial crops with a high water requirement can no longer thrive there. Although an accurate definition of a dry period, harmful to rubber cultivation, does not exist, the Dry Zone of Sri Lanka does not offer suitable rainfall conditions for *Hevea.*

It is therefore the Wet Zone of Sri Lanka which offers a favourable, although not even, rainfall distribution round the year for rubber cultivation. But there are still existing significant seasonal and monthly rainfall fluctuations which can be shown by the monthly percentage ratios against the annual total. In an ideal case of a completely even rainfall distribution round the year, each of the 12 months of a year would get an 8·3% ratio of the annual total. On this basis the monthly percentage values for three selected stations in the Wet Zone lowlands have been calculated. These are Colombo, Galle and Ratnapura (see Table 1). In addition, the values for a typical Dry Zone station (Anuradhapura)

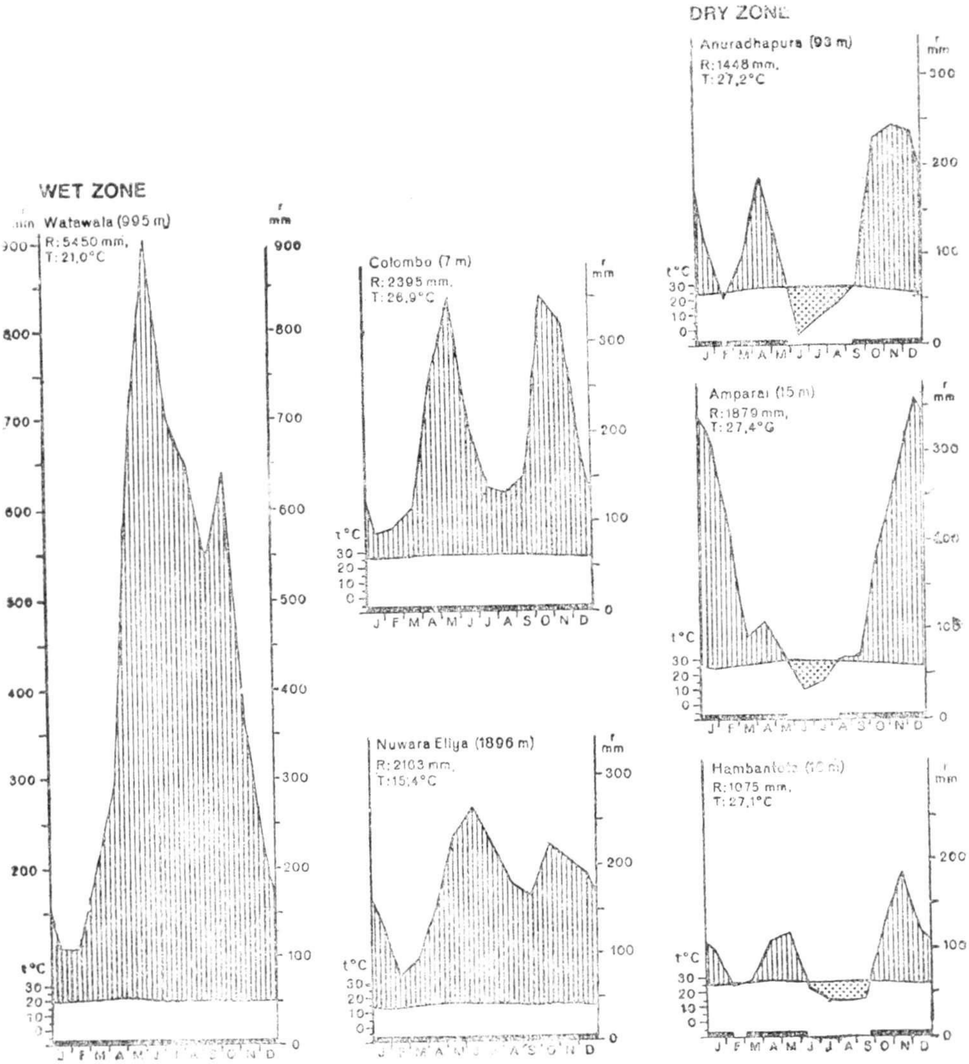

WET ZONE
Watawala (995 m)
R: 5450 mm,
T: 21,0°C
Colombo (7 m)
R: 2395 mm,
T: 26,9°C
Nuwara Eliya (1896 m)
R: 2103 mm,
T: 15,4°C
DRY ZONE
Anuradhapura (93 m)
R: 1448 mm,
T: 27,2°C
Amparai (15 m)
R: 1879 mm,
T: 27,4°C
R: 1075 mm,
T: 27,1°C

Fig. 1.

are also given. For all three Wet Zone stations, a wide range of the monthly percentage ratios can be seen, for Colombo from 4 to 15%, for Galle from 5 to 14%, and for Ratnapura from 4 to 13%. Thus, it can be followed that the monthly deviation of rainfall reaches nearly a 100% surplus and a 50% deficit — in relation to the 8·3% monthly average which would be valid for an even rainfall distribution round the year. It is in particular the Northeast monsoon season which shows a deficit, while the two intermonsoonal seasons are surplus periods. This type of rainfall corresponds with the climatic diagrams (see Fig. 1).

Table 1. *Monthly percentage ratios of rainfall against the annual total for selected meteorological stations in Sri Lanka*

	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.
Colombo	3·7	4·0	4·9	10·9	14·7	8·9	5·8	5·2	6·4	14·8	13·5	7·3
Galle	4·5	4·6	4·6	10·0	12·0	8·8	6·8	7·1	7·1	14·1	12·8	7·4
Ratnapura	3·9	4·7	6·3	8·8	12·7	11·9	7·9	8·4	8·1	12·8	9·1	5·5
Anuradhapura	8·5	3·7	6·8	12·9	6·9	1·3	2·2	3·2	4·8	16·1	17·1	16·7

The annual totals are as follows (averages 1931 to 1960):

Colombo	2,395 mm
Galle	2,513 mm
Ratnapura	3,888 mm
Anuradhapura	1,447 mm

However, comparing the monthly percentage ratios of the three Wet Zone stations with the corresponding values for the Dry Zone station Anuradhapura (see Table 1) it can be clearly followed that in the Dry Zone a pronounced, long dry period exists which, on the contrary, is missing in the Wet Zone.

From the rainfall conditions as a whole, the requirements for rubber cultivation are fulfilled in the Southwestern sector of Sri Lanka which is encircled by the 2,500 mm — isohyet, as described above. This part is not only characterized by a favourable annual rainfall total, but also by a fair distribution of rainfall round the year.

Strong, gusty winds which have also been pointed out to be an agroclimatic index of general significance to rubber cultivation occur in Sri Lanka, particularly in the well known 'Kachchan' blowing, which occurs as a foehn-like wind on the eastern flanks of the Central highlands during the Southwest monsoon period. In addition, meso-scale local winds may also temporarily and occasionally affect certain parts of the highlands, however, without any far-reaching effects.

On the basis of the major temperature and rainfall requirements for rubber cultivation, the agroclimatic potential of rubber lands in Sri Lanka can be worked out as

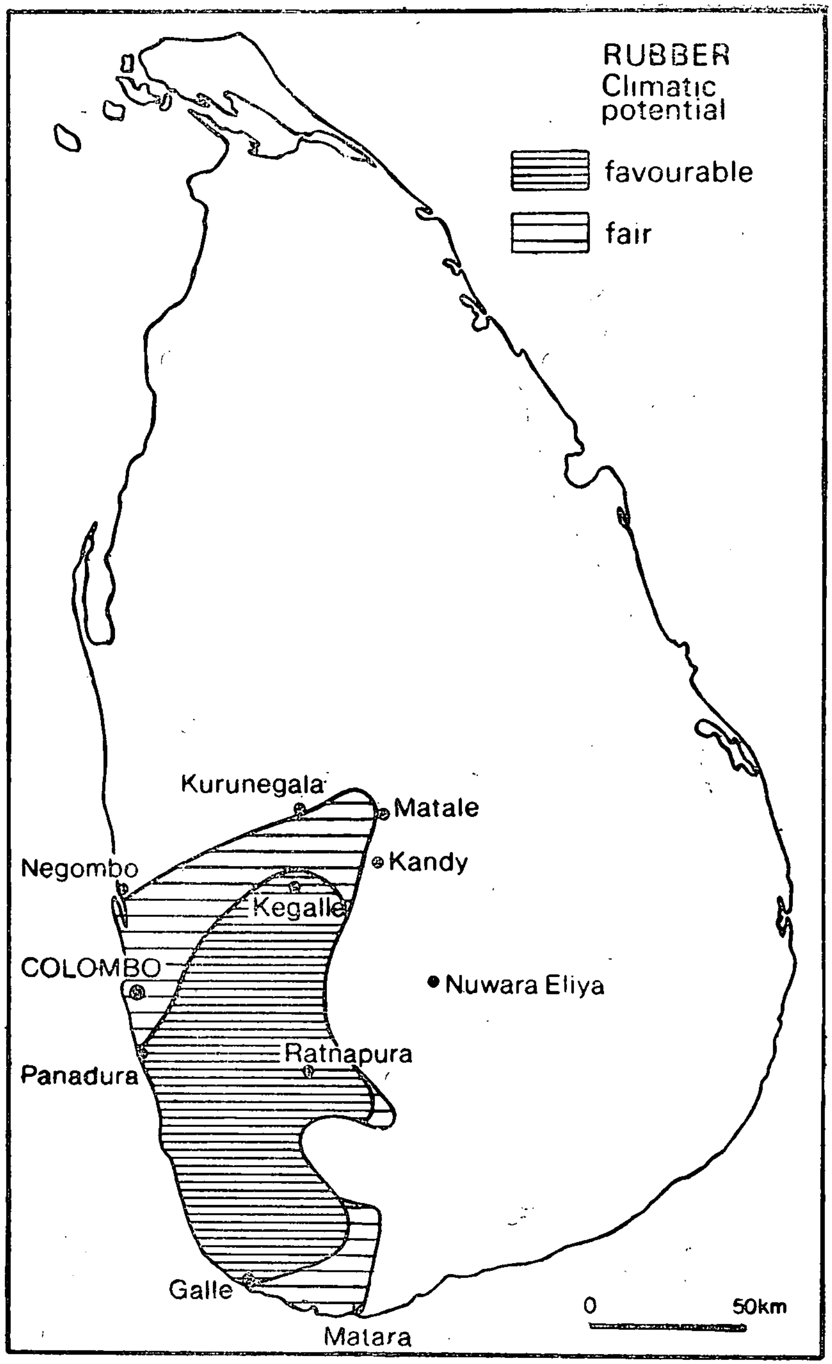

RUBBER
Climatic
potential
favourable
fair
Kurunegala
Matale
Kandy
Negombo
Kegalle
COLOMBO
Nuwara Eliya
Ratnapura
Panadura
Galle
Matara
0
50km

Fig. 2.

follows. All the particular agroclimatic indices are fulfilled only in a small section of Sri Lanka which is restricted to the Southwestern lowlands, roughly between Panadura and Galle and reaching in the interland upto the 300 mm contour line. The favourable rubber lands, therefore cover the wet Southwestern lowlands and the lower part of the wet mid-country. In administrative terms, it is the Kegalle, Kalutara and Galle Districts as well as the Western half of the Ratnapura District which offer *favourable* growing conditions for rubber. Fair agroclimatic conditions for rubber cultivation still exist in the Matara and Colombo Districts and in the Southern parts of the Kurunegala District where all except one of the agroclimatic indices are fulfilled (Fig. 2).

The boundaries worked out for rubber cultivation in Sri Lanka are in a vertical direction a warmth deficit boundary, and in a horizontal direction a water (rainfall) deficit boundary.

The agroclimatic-*potential* rubber lands in Sri Lanka widely coincide with the present day distribution of rubber cultivation in Sri Lanka, which is mostly carried out in the Kegalle, Kalutara and Ratnapura Districts. From the agroclimatic viewpoint, therefore, an extension of profitable rubber lands hardly seems possible. Yet, on the other hand the actual distribution of rubber lands can be proved to be a favourable one as far as the climatic conditions are concerned. For future development of rubber cultivation in Sri Lanka, cropping *intensification* seems of major importance in order to achieve a higher latex production. In this direction, in particular, rubber replanting schemes need further attention.

REFERENCES

DOMROES, M. *The Agroclimate of Ceylon.* Wiesbaden (Steiner verlag) 1974.