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INTERCROPPING *HEVEA* REPLANTINGS DURING THE IMMATURE PERIOD

By

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Importance of intercropping

Most of the *Hevea* plantations in Sri Lanka are located in the low country wet districts which receive rainfall during both the North East and South West monsoon periods. Under such conditions, a plantation of *Hevea* budgrafts normally takes around 6 years to reach tappable girth. Limited acreages of *Hevea* plantations are also found in the drier parts of the country such as in the Matale, Kurunegala, Badulla and Moneragala districts. Due to limited rainfall conditions in these districts, a plantation of *Hevea* budgrafts takes much longer, sometimes up to 9 years to reach tappable girth. During this period of immaturity, it has been possible to utilize the inter-row space for growing a selection of crops that would give an income to the estate owner until the *Hevea* trees are brought into tapping in about the seventh year from planting. This is particularly important for the smallholder who had so far been reluctant to replant his old and low yielding rubber due to the long period of time he has to wait until he gets some return from his land.

In Sri Lanka, particularly in the major rubber growing districts, rubber is generally replanted on an approximately 33 year cycle. If such replanting is carried out regularly, approximately 3 percent of the total rubber acreage in Sri Lanka will be replanted each year. On a national level therefore, approximately 15 percent of the rubber acreage would be immature at any given time and would have the potential to be intercropped. This represents an extent of about 30,000 hectares.

Type of crops

In Sri Lanka, the high annual rainfall renders the steep terrain, in which most rubber is grown, subject to soil erosion if the land is clean weeded. This factor narrows down the scope for intercropping to mostly perennial crops that do not require clean weeding and regular cultivation of soil. Apart from this, a suitable crop should ideally have the following characteristics.

(a) Non-competitive with rubber
(b) Suitable for the climatic and soil conditions of the area
(c) Less labour intensive
(d) No necessity for irrigation or regular watering
(e) Freedom from diseases, particularly those that affect rubber
(f) Should have ready markets

Bearing these in mind, the Rubber Research Institute of Sri Lanka has carried out trials with a wide range of crops and the following have crystallized out as being suitable for interplanting among young rubber in the wet districts.

Banana, passion fruit and pineapple

These crops require only circle weeding round each plant, just like in rubber, while the rest of the land can remain under ground covers. Pineapple however, is an exception that requires clean weeding and is therefore suitable for cultivation on flat or gently sloping land. For intercropping, rubber is best planted with a minimum inter-row distance of 6 m.

Effects of intercrops on rubber

We have carried out three large scale experiments involving the inter-planting of banana, passion fruit and coffee among newly planted rubber. In each experiment the rubber is planted at an initial density of 450 points per hectare with a spacing of 6 m between rows. A single row of banana, passion fruit or coffee is planted centrally between each pair of rubber rows with the following spacing along the row.

Banana	—	3·7 m
Coffee	—	3·7 m
Passion fruit	—	7·5 m

All three crops are included in each experiment and the three experiments are sited in three districts, namely Ratnapura, Kalutara and Kegalla. The experimental design is a randomised layout with each treatment replicated six times. The average girth measurements of rubber recorded at 3 years of age are given in Table 1.

Table 1. *Mean girth (cm) of* Hevea *budgrafts at 3 yrs of age in three field experiments*

Crop	Experiment I	Experiment II	Experiment III
Banana	21·75	21·18	29·82
Passion fruit	21·61	19·93	29·58
Coffee	21·77	21·53	30·50
Control	21·15	19·13	31·22

The girth differences between the treatments are statistically not significant. This means that interplanting these crops has not affected the growth of rubber up to the 3rd year from planting.

In the case of pineapple, there was a large scale experiment sited on flat land in the Kalutara District. The treatments consisted of 1 row, 2 rows, 3 rows and 4 rows of pineapple planted centrally between each pair of rubber rows and a control without pineapple. The five treatments were replicated six times.

The pineapple plants were spaced 45·7 cm along the row and 0·6 m between rows. Where 4 rows of pineapple are planted, there was a central path 1·5 m wide between each pair of pineapple rows to permit weeding and other cultural operations. At the above spacing, four rows of pineapple plants between each pair of rubber rows would result in an approximate stand of 9,400 pineapple plants per hectare when no allowance is made for rocks and paths. The girth measurements of rubber budgrafts in the experimental area were taken at 3 years of age and are summarised in Table 2.

Table 2. *Mean girth (cm) of* Hevea *budgrafts intercropped with pineapple at 3 years of age*

Treatment	Mean girth (cm)
Pineapplc — 1 row	16·57
,, — 2 rows	16·43
,, — 3 rows	16·32
,, — 4 rows	18·10
Control	13·78

LSD — 2·51

The girth differences between the control plots and the intercropped plots have been statistically significant. This means that the growth of rubber in the intercropped plots has been better than the control plots.

Bananas

The cultivation of bananas as an intercrop offers attractive prospects as it has the following advantages :

1. grows well in most parts of the country
2. less labour intensive than other crops
3. requires less capital investment than others
4. has ready markets in Sri Lanka.

However, experiments that have been carried out so far show a marked influence of rainfall on yield. One difficulty in estimating the yield of bananas in experimental plots had been due to thefts which are difficult to prevent. Therefore in experimental areas the bunches were numbered serially and before they are fully mature the number of fruits per bunch were counted and the value of bunches estimated. Table 3 gives a summary of the estimated mean value of bunches in three rubber growing districts.

Table 3. *Mean value (Rs.) per bunch of bananas in three field experiments*

District	No. of trees	Mean value per bunch	
		1st year	2nd year
Ratnapura	180	20·63	23·98
Kalutara	180	17·53	17·95
Kegalla	240	7·30	5·95

The mean value reflects the size of bunches harvested, the largest of which were recorded from Ratnapura District. Poorest yields were recorded in the relatively dry Kegalla District.

Table 4 gives the estimated income in rupees per hectare for the three districts according to which the lowest income has been recorded for the Kegalla district.

Table 4. *Estimated income in Rs. per hectare of bananas in three field experiments*

District	Number of plants	1st year	2nd year	3rd year
Ratnapura	180	5,362	10,030	7,225
Kalutara	180	3,092	3,290	4,815
Kegalla	240	382	340	232

Passion fruit

Although passion fruit can be grown in most parts of Sri Lanka, cultivation on a commercial scale is at present confined to four districts, namely Kalutara, Ratnapura, Galle and Avissawella the reasons being the following.

1. Availability of marketing facilities
2. Suitability of climatic conditions for optimum growth of vines and yield of fruit.

Here again, due to thefts, the yield of vines in experimental plots were evaluated by counting the immature fruits at suitable intervals. The counted fruits were marked with a dot to prevent a re-count. At harvesting time, a random sample of 100 fruit were drawn, weighed and from the resulting value, the weight of the total crop was estimated.

Table 5 gives a summary of the mean yield of passion fruit in three field experiments located in three rubber growing districts.

Table 5. *Mean yield of passion fruit in kg per plant in three field experiments*

District	No. of plants	Mean yield 1st year	Mean yield 2nd year
Ratnapura	109	6·39	12·00
Kalutara	99	5·81	14·50
Kegalla	142	2·18	2·50

Ratnapura and Kalutara Districts with their well distributed rainfall have recorded the highest yield of fruit per vine.

Table 6 gives the estimated income from growing passion fruit as an intercrop in three experimental areas.

Table 6. *Estimated income in Rs. per hectare of passion fruit crop in three field experiments*

Districts	No. of plants	Estimated income 1st year	2nd year	3rd year
Ratnapura	109	11,510	21,255	7,885
Kalutara	99	10,452	21,407	—
Kegalla	142	3,927	4,257	3,695

According to data in Table 6, passion fruit had so far been the most profitable crop.

Pineapple

The cultivation of pineapple as an intercrop has not been very popular so far with smallholders. This may probably be due to the following reasons.

1. It requires a higher capital investment
2. It is more labour intensive

In one large scale experiment involving an extent of approximately 1.25 hectares, an average income of Rs. 11,752 per hectare was recorded at the end of the second year in 1983. In certain locations, particularly in the Kalutara district, pineapple plants were also observed to the affected with a dry rot caused by the fungus *Ceratocystis paradoxa*.

PROGRESS AND DEVELOPMENT OF THE SMALLHOLDING SECTOR OF THE NATURAL RUBBER INDUSTRY IN MALAYSIA

By

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ABSTRACT

The paper reviews the progress of the rubber smallholding sector and its importance to the Malaysian economy. Current development efforts undertaken by the Government aim at further increasing the productivity and income of rubber smallholders by way of a dynamic replanting program which incorporates various recent technological inputs and innovative extension efforts. The development of the Malaysian rubber smallholding sector today is more and more geared to the group and integrated agricultural development approach where technology and development package derived from research findings on rubber and other viable agricultural enterprises are consciously adapted and transferred to smallholders at both the immature and mature phases of rubber growth. Such technologies include, among other things, rational felling policy for rubber wood utilisation, replanting with high yielding rubber clones, efficient exploitation systems, modern farm management techniques and profitable integrated and mixed farming systems. Wider application and extension of this integrated technology and farming systems approach in smallholder development can ensure the continuity and socioeconomic viability of the smallholding sector as the most important and efficient production unit in the Malaysian agricultural economy.

INTRODUCTION

Total world demand for rubber (NR+SR) today amounts to about 13 million metric tonnes annually. From this total, about 30% of the world supply comes from NR, 41% of which from Malaysia mainly from the smallholding sector. Table 1 shows that in Peninsular Malaysia the smallholdings occupied 73% of land under rubber, or about two-thirds of the land area under agricultural crops, and produced 63% of the total rubber production in 1983. NR thus contributes to a major source of the country's employment and foreign exchange earnings. Numbering about half a million farms, the smallholding sector with an average family size of 5·5 persons supported directly or indirectly about three million people or 30% of Peninsular Malaysia's population and NR alone contributes to 15% of total export earnings in 1983.

Progress of the smallholding sector

In terms of hectarage and production, the rubber smallholder sector has made a tremendous expansion especially smallholdings under RISDA. Planted hectarage increased from 1 077 300 hectares in 1970 to 1 205 700 hectares in 1980 while production increased from 594 757 tonnes in 1970 to 877 090 tonnes in 1980 and yield increased from 753 kg/ha/year to 1 104 kg/ha/year over the same period (Table 2).

Table 1. *Rubber hectarage and production in Malaysia 1981 — 1983*

Regions and Sectors	Area under rubber (Hectarage)				Rubber production (Tonnes)			
	1981	1982	1983	% (1983)	1981	1982	1983	% (1983)
Total Malaysia	2 030 000	2 010 135	2 009 900	100	565 000	1 516 585	1 561 992	100
Peninsular Malaysia	1 720 000	1 700 700	1 702 400	85	500 000	1 478 982	1 521 617	97
Sabah & Sarawak	310 000	309 435	307 500	15	63 000	37 603	40 375	3
Estates	490 000	473 200	464 000	27	597 800	576 721	560 114	37
Smallholdings	1 230 000	1 227 500	1 238 400	73	967 200	902 261	961 503	63

Sources : Rubber Research Institute of Malaysia Annual Reports 1981, 1982, 1983
Rubber Monthly Statistics, Department of Statistics, Malaysia

Table 2. *Planted hectarage, production and yield on smallholdings in Peninsular Malaysia (1970 — 1980)* *('000 Hectares)*

Year	FELDA	RISDA	FELCRA	Others[a]	Total	Total Productions (tonnes)	Estimated Av. Yield (kg/ha)
1970	59·8	436·0	5·7	575·8	1077·3	594 757	753
1971	67·6	459·2	8·3	551·4	1086·5	608 865	735
1972	76·2	482·6	15·0	518·2	1092·0	598 815	703
1973	88·8	511·2	21·5	483·1	1104·6	791 519	927
1974	94·3	534·8	23·6	464·9	1117·6	800 972	1039
1975	105·1	555·9	26·1	444·5	1131·6	817 505	1068
1976	114·7	570·2	26·2	419·6	1130·7	884 542	1093
1977	124·6	583·0	28·5	409·2	1145·3	883 919	1102
1978	145·2	596·3	31·2	403·0	1175·7	888 047	1104
1979	156·8	610·6	35·1	392·6	1195·1	890 053	1105
1980	168·9	626·3	41·8	368·7	1205·7	877 090	1104
1981	—	—	—	—	1226·2	882 300	—

a Include independent smallholdings (Including those assisted by RISDA) and organised smallholding other than those in FELDA and FELCRA Schemes.
b *Source :* MRRDB
Source : Department of Statistics, West Malaysia, Rubber Statistics Handbook.

The replanting rate as shown in Table 3 indicates that in 1970, 90% of the estates have been replanted compared to only 46% in the smallholdings. By 1980, the rate has increased to 99% for the estate and 72% for the smallholdings. The replanting rate for smallholdings in 1982 was estimated at 78%. In terms of replanted hectarage, Table 4 shows hectarage replanted since 1975 and estimated replanting programmes up to 1985. An annual average of 17 000 hectares of rubber were replanted between 1975 — 82. The last decade has thus seen a revitalising of the trees in the smallholdings through replanting. Past trends have also shown replanting activities to increase during periods of low rubber prices where the industry took stock of itself and reinvested in replanting. Indications are that during the current low rubber price a similar reinvestment will occur as indicated by the replanting projections for 1983 — 85 in Table 4.

Table 3. *Percentage under replanting (1970 — 1982)*

Year	Estate %	Smallholding %
1970	90	46
1971	92	49
1972	93	52
1973	95	56
1974	95	59
1975	97	62
1976	98	64
1977	98	66
1978	98	68
1979	99	70
1980	99	72
1981	—	75
1982	—	78*

* Up to 1982, an estimated 791,969 hectares (78%) on smallholdings have been replanted.

Table 4. *Hectarage replanted since 1975 and estimated replanting up to 1985*

Year	Hectarage replanted (rubber only)	Hectarage replanted (other crops)	Total hectarage replanted (all crops)	Estimated replanting (ha all crops)
1975	20 709	12 470	33 179	—
1976	14 250	5 485	19 735	—
1977	12 789	5 419	18 208	—
1978	13 255	5 943	19 198	—
1979	14 186	8 205	22 391	—
1980	15 300	7 685	22 985	—
1981	22 624	6 827	29 451	26 710
1982	23 699	7 484	31 183	30 271
1983	—	—	—	33 355
1984	—	—	—	36 422*
1985	—	—	—	38 446*
	136 812	59 518	196 330	165 204

* Including replanting on Felda Schemes :
1984 — ± 3643 hectares
1985 — ± 4048 hectares
Source : RISDA

The expected achievement in replanting for the period 1981 — 1985 is as shown in Table 5. A total of about 152 000 hectares are expected to be replanted at a total cost of nearly $457 million by the end of the Fourth Malaysia Plan period.

Table 5. *Expected achievement in replanting program for the period 1981 — 1985 in Peninsular Malaysia*

Year	Hectare	Cost ($)
1981*	29 550	81 621 402
1982	30 467	96 715 581
1983	33 355	121 908 783
1984	28 651	76 567 000
1985	29 697	80 081 000

* Actual achievement
Source : RISDA

Problems in the smallholding sector

Though smallholding rubber acreages have increased significantly over the years vis-a-vis the estate sector, its productivity still lags behind that of the latter due mainly to structural problems. The average rubber yield from the smallholdings is relatively lower at 1 104 kg/ha/yr, compared to the estates yield of 1 507 kg/ha/yr (Table 2). Socio-economic institutional and technological inadequacies which include the uneconomic sized holdings, ageing labour, inefficient production and management techniques together with the vagaries of the market on smallholders' produce, account for the low productivity and the high incidence of poverty among rubber smallholders at 41·3% in 1980. They still form the single largest poverty group in the country numbering about 175 900 poor households. Their percentage among the total poor was the highest in the country at about 26·4% in 1980. In terms of average monthly family income, individual rubber smallholders were earning about M$ 240/-. However, rubber smallholders in land development schemes enjoyed a much higher level of net income of M$ 450/- monthly, owing to their larger farm size in 1983. Those with even larger land holdings of 12 acres earned a net average income of M$ 1041/- per month during the same period.

In view of these structural problems which resulted in low productivity and income particularly among the individual smallholders, poverty alleviation programs in the rubber smallholdings have to be made more comprehensive. Such programs cover the total agricultural activities that can be developed to raise the general level of farm productivity and income from the rubber holdings.

Government efforts to raise farm productivity and income in smallholdings

Various steps were instituted by the Malaysian Government through its development agencies to raise farm productivity and income among rubber smallholders. These include developing them on organised group basis through various development strategies like Group Replanting Schemes and mini estates in addition to the established and organised land development schemes of FELDA, FELCRA, State Schemes and so forth. Future development for the individual smallholders, where the problem of poverty is most acute, is increasingly being organised on the basis of group replanting and integrated agricultural development projects in line with the National Agricultural Policy. Such organised and integrated farming systems approach enable an organised transfer of technology both for rubber and other related feasible agricultural activities. This multi-activity approach can ensure future viability and efficiency of smallholdings as enduring production units at par with the organised schemes and mini estates in achieving its socio-economic objectives.

Smallholders development through the Integrated Agricultural Development (IAD) approach in Rubber Group Replanting Schemes

The Government rubber replanting program has progressed significantly since 1970. By 1982, about 78% of smallholdings have been replanted. In order to enhance further this replanting activity the IAD approach is advocated to achieve higher productivity and income in the smallholder sector. The IAD approach in group replanting embarks on the consolidation of the 1 — 2 ha individual rubber smallholdings into more or less larger contiguous block or area of 10 — 20 ha for efficient adoption of various modern and appropriately developed and adapted technologies at the immature and mature phases. The rationale for the selection of this size group is based on the fact that in Peninsular

Malaysia more than 70% of the smallholdings are owner-operated and fall under the 1·2 — 2·0 ha, group. These entities fall out of the mini estate development concept and more often than not enjoy only peripheral effects of new technologies.

The planning, implementation and coordination of the IAD projects are done by the sponsoring authority, which in this case is the RRIM with assistance forthcoming from RISDA and other related development agencies. Project financing comes from the RISDA replanting grant for rubber and production credit from the sponsoring authority for other agricultural projects. The project cycle lasts through the immaturity period of rubber from which point other mature rubber technologies take on. The objectives of this multi-activity concept of technology transfer to smallholders are :

- To provide the smallholders with 'package-deal' technologies in order that they might benefit from all new technologies available from research and development in the RRIM ;
- To raise general farm productivity by increasing farm production and family income in more diverse and efficient ways ;
- To narrow the productivity gap between the smallholdings and estates sectors ;
- To serve as demonstration plots to other surrounding smallholders on the benefits of adopting new technologies available to them.

Smallholders development — Recommended technologies available at the pre-planting, replanting, immature and mature phases of rubber growth.

The recommended technologies to increase the productivity and income of rubber smallholders at the various growth phases of rubber trees are as follows :

(i) Pre-Replanting Phase	: Yield stimulation
(ii) Replanting Phase	: Sale of rubber wood, the use of high yielding clones and advanced planting materials, efficient field maintenance programmes such as the growing of cover crops, fertiliser application and weed control.
(iii) Immature Phase	: Planting with cash-crops and/or poultry rearing
(iv) Mature Phase	: Poultry rearing and/or sheep rearing.

Yield stimulation

Stimulation with Ethephon can substantially increase yield in a wide range of rubber cultivars. This approach to increase yield is now a routine practice in the commercial plantations with rubber trees fifteen years and older.

Appropriate stimulation practices are now available to improve the economic yield of rubber smallholdings. The procedures involved minimal use of stimulant and judicious methods of application. These have been geared to suit smallholdings tapping and cultural practices. It is estimated that about 60% of the potential holdings with less than 10 hectares can be stimulated with Ethephon. Additional income of $ 488/- ha/yr for mature holdings and $ 1245/- ha/yr for old holding can be realised from yield stimulation after deduction of input costs.

Sale of rubber wood

From replanting the rubber wood can be sold to generate extra income for smallholders. It is estimated that 100 — 120 tonnes of rubber wood are obtainable from one hectare. At a price of $ 20/- per tonne waste wood, an income of $ 200/- — $ 240/- can be expected from one hectare of smallholding if there is a buyer for the wood.

Studies show that 40% of the waste wood can be recovered for sawn timber. Table 6 shows the estimated tonnage of sawable rubber wood obtainable per hectare from some clones on smallholdings. A greater output of wood can be expected from the GT 1, PR 107 and PB 5/51 clones when they are due for replanting at the age of around 30 years. On the average, about 40 tonnes of sawable rubber wood per hectare can be obtained at the time of replanting.

Table 6. *Estimated tonnage of sawable rubber wood obtainable per hectare from some clones*

Clone	Age (years)	Approximate No. of stands/ hectare	Mean girth 150 cm above ground (cm)	Tonnage of sawable wood per hectare
RRIM 600	26	200	103	66
Tjir 1	25	250	83	42
GT 1	18	250	79	37
PR 107	18	250	82	32
PB 5/51	19	250	83	32

Clones

For smallholdings to be replanted it is mandatory for these holdings to replant with high yielding clones. The clones recommended for smallholdings are shown below and their yield profiles are shown in Table 7.

(a) Recommended clones for individual smallholdings

CLASS I : GT 1 ; PR 217 ; PR 255 ; PR 261 ; RRIM 600 ; RRIM 712

CLASS II : PB 280 ; RRIM 729 ; PB 235

Table 7. *Mean yields*[a] *of recommended clones*[b] *(Classes I and II) for smallholdings*

CLONE	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
CLASS I															
RRIM 600	720	1210	1600	1860	2310	2320	2350	2470	2700	2360	2190	2040	2660	2940	3260
RRIM 712	690	1490	2010	2330	2230	2290	2610	2290	2560	2760	2250	—	—	—	—
PR 255	1170	1500	1850	2250	1920	2070	2300	2140	2110	2050	2380	2210	2140	2100	2120
PR 261	860	1290	1610	1840	1830	2240	2360	2420	2260	2120	1860	1600	1690	1870	1720
PB 217	570	1050	1380	1520	1580	2200	2200	2270	1950	2020	2110	2210	2050	—	—
GT 1	700	1180	1410	1640	1570	1960	2280	2340	2310	1880	2040	1700	1530	1670	1640
CLASS II															
PB 235	1370	1870	2280	2300	2000	2060	3230	2530	2560	2530	2170	3290	—	—	—
RRIM 729	800	1360	1920	2030	2210	2090	—	—	—	—	—	—	—	—	—
PB 280	1090	1500	1890	2180	2240	2160	—	—	—	—	—	—	—	—	—

a. In kilogram per hectare per year
b. Data from large-scale clone trials

(b) Recommended clones for block-planted smallholdings

CLASS I : GT 1 ; PB 217 ; PR 255 ; PR 261 ; RRIM 600 ; RRIM 712

CLASS II : AVROS 2037 ; PB 28/59 ; PB 255 ; PB 260 ; PB 280 ; PB 235 ; RRIM 527 ; RRIM 729.

Planting materials

Two-whorl polybag planting materials are recommended since they are suitable for smallholding conditions. These materials can be prepared by the smallholders themselves to prevent problems of logistics when their supplies are organised through tenders. The use of other advanced planting materials such as maxi stumps is also recommended for smallholdings. These planting materials can reduce the immaturity period to 4 — 4½ years in the case of maxi stumps and 4½ — 5 years in the case of polybag materials. Besides their use also result in higher planting success, uniform trees and high percentage of tappability.

Maintenance

In addition to recommended clones and planting materials, other agricultural practices have to be followed to ensure the long term productivity of replanted holdings. This includes efficient fields maintenance programmes namely, cover cropping, fertilizer application and weed control.

(a) Cover crops

Legume covers are recommended in the interrows of rubber in smallholdings. The advantages are that cover crops protect soil from erosion, add organic matter to the soil, keep the soil cool, fix atmospheric nitrogen and control weeds.

(b) Fertiliser application and weed control

Good management practices particularly judicious application of fertiliser coupled with efficient weed control can lead to increases in yield of 25 — 30% and overall productivity of rubber trees in the smallholdings. Continued use of fertilisers based on the present discriminatory fertiliser recommendation also result in residual benefits through better bark regeneration.

Integrated farming as a source of income in rubber smallholdings

At the immature and mature phases of rubber growth, income of smallholders can be increased through integrated farming in rubber holdings. Integrated farming can be carried out along the following combinations of farming systems namely (a) cash crop — rubber, (b) poultry — rubber, (c) sheep — rubber and (d) poultry — sheep — rubber.

(a) Cash - Crop - Rubber

During the first 3 years of rubber cultivation about 80% of the land, under rubber is suitable for planting with intercrops. Crops that require less than 3 years to mature may be cultivated in the rubber interrows. Thus maize, groundnut, soybean and banana can be successfully cultivated on flat to undulating smallholdings, while banana is suitable on hilly areas with slopes greater than 8°.

(b) Poultry - Rubber

Other than for intercrops, poultry sheds may be constructed in the rubber interrows for poultry rearing. Where day-old chicks, feed and market are available, poultry rearing especially broiler production is suitable for smallholders.

(c) Sheep - Rubber

After about three years of growth, the leaves of the rubber trees normally shade the interrows, and the cultivation of intercrops is not economical. At this stage sheep can be integrated under rubber. Results of integrating sheep, particularly Dorset Horn crossbreds, with rubber have been encouraging and acceptable to smallholders since they provide a steady income stream to smallholders and also feed on the weeds thus reducing the cost of weed control in the holdings.

(d) Poultry - Sheep - Rubber

This combination in the farming system is the most beneficial to smallholders who have limited land and capable of raising a few heads of sheep and some poultry. These animals can serve as important additional income earners.

Farming practices

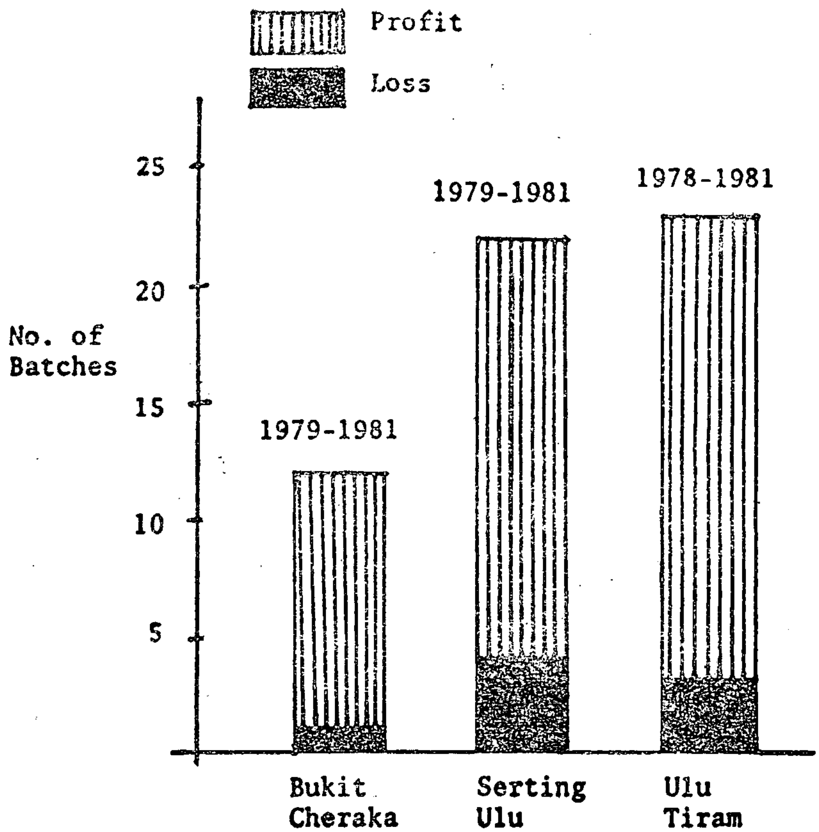
The above farming systems have their own merits and demerits and their benefits are now discussed under types of farming practices as follows :

(a) Cash crops

Table 8 shows the comparative advantage of planting with the recommended crops. Groundnut requires the highest cost input while maize gives the highest net return to investment provided all the fresh cobs are sold at the right time. Land preparation, labour and fertiliser account for a large portion of the production cost.

(b) Poultry

Broilers are more suitable than egg production for rubber smallholders because of quick turnover and less management problems. The average production cost (Table 9) was slightly higher than commercial but lower than smallholders' farms receiving no supervision. The average income per smallholder per year is shown in Fig. 1. Although these figures showed lucrative returns, the net family income varied among smallholders and time of year. The most important factors that could influence income are :



No. of bird batch^{-1}:	500	500-1000	150-300
(Batch year^{-1}):	(4)	(6)	(5)
Total broilers produced:	5,950	11,940	4,800
Av. Income year^{-1}:	$1,990	$2,380	$530

Fig. 1. Average yearly income from broiler project.

- Supply of high quality day-old chicks when needed,
- Supply of unadulterated and high quality feed,
- High cost of day-old chick and feed, and
- Availability of market and suitable market price.

Table 8. *Production costs and return ($/Ha/crop) from 4 types of intercrops planted during the first 3 years of rubber cultivation*

Items	Types of crops Groundnut ($)	Maize ($)	Soybean ($)	Banana* ($)
Land preparation	340	340	340	130
Planting materials — seeds	450	60	75	160
Fertilizer	250	440	260	600
Weedicides	40	40	50	45
Pesticides	120	30	125	20
Labour (Family)	600	330	540	25
Total production cost	1,800	1,240	1,390	1,205
Yields (kg)	3,500	25,000 cobs	1,200	6,274
Price (farm-gate)	75c/kg	10c/cob	$ 1·30/kg	$ 0·30/kg
Gross income	2,625	2,500	1,560	1,882
Profit	825	1,260	170	677

* Mean of 3 croppings

Table 9. *Average cost of broiler production under smallholdings*

Item		(M$) bird^{-1}
(a)	Day-old chicks	1·00
(b)	Feed : Starter	0·85
	Grower	2·40
(c)	Veterinary medicines	0·10
(d)	Other costs (electricity, water etc.)	0·18
(e)	Depreciation on fixed assets (shed, feed and water utensils)	0·32
	Total	4·85

(c) Sheep rearing

Integrating sheep with rubber can bring direct and indirect benefits to the rubber smallholders. The direct income is through the sale of livestock as mutton, and with the crossbred, the potential for wool and pelt is bright. The Economic viability of small scale sheep rearing under rubber is given in Table 10.

Table 10. *Estimated cost of production and income for local sheep and 50% Dorset Horn crossbred*

Items	Initial Stock plus 1 Stud 5	10	15	20
1. *Shed built with local materials (0·7 mr/²earning) ($)	300 (8·4 m²)	530 (17·5 m²)	780 (26·0 m²)	1000 (35·0 m²)
2. Fencing if necessary. Cost is too high.	Depends on the need and area. More accurate estimates can be obtained at each locality			
3. Animal cost ($ 80 for female and $ 100 for male)	450	800	1100	1000
4. Cost of planting grass (if necessary)	80 (0·1 ha)	120 (0·15 ha)	160 (0·20 ha)	180 (0·225 ha)
5. Cost/year ($)	154	276	403	578·50
6. No. of animal sold	4	11	18	25
7. **Income after 1½ years Income/year (P)	a. 62·0 b. 266·0	318·0 879·0	568·0 1486·0	831·5 2106·5

* Include area for new born lamb.

** Local breed : a. 18 kg @ 3·00 per kilo live-weight
b. Crossbred 50% Dorset Horn. 1 year = 35 kg
} To deduct the depreciation cost of shed, Vet. medicine and others.

The average cost of vet. medicine, salt lick etc. @ $ 2·50 per animal per year.

CONCLUSION

The total land area replanted since the launching of the replanting scheme in 1953 now constitute about 75% of the total registered rubber area. Under the Dynamic Production Policy, rubber replanting with higher yielding and earlier maturing planting materials together with better exploitation techniques can bring about further improvement in productivity and income of rubber smallholders. Through appropriately developed technology packages and agricultural support facilities, namely efficient supply of farm inputs and extension of farm management techniques for rubber and related non-rubber activities smallholders' productivity and income base can be broadened and improved.

The current economic recession and inflation which resulted in the simultaneous decline in the rubber price and increase in the cost of inputs and general cost of living have bitten hard into the rural sector resulting in migration of rural youth to the cities and other growth areas. This continuing rural-urban migration which brings about the attendant problems of labour shortages in the rural rubber sector suggests the need to continuously reallocate scarce resources and increasingly mechanise various farm operations in order to make it more attractive for rural youth to remain behind and operate farms as on-going viable enterprises. The rubber-based rural economy thus needs to be stimulated with additional economic activities through the IAD to supplement that of rubber.

Being inelastic in nature the rural smallholders' rubber economy cannot be readily diversified (nor is it deemed desirable to do so) in the face of the current unfavourable rubber price trend. Thus under this present conditions it is only through the increase in the volume of rubber production by yield stimulation both at the old tree phase (3 years to felling) and mature phase (Panels C & D) can smallholders' income from rubber be increased in the short-term. In addition, other non-rubber farm activities like intercropping and cash-cropping (at the immature rubber phase) and mixed farming (at the mature rubber phase) can help broaden the income base of rubber smallholders in the medium term. As a long-term measure to increase the productivity and income of rubber smallholders, effective replanting programme using the best yielding clones and early maturing planting materials and best management techniques together with the latest technology in integrated farming of inter-crops, cash crops and animal husbandry at the various phases of rubber planting should be advocated.

Thus at all the phases of rubber planting there are important investment decisions to be made. Methods of discovering the optimum combination in the farming-mix at the various planting phases and the scale of operation will ensure the long-term viability of farming rubber on the smallholding model. The crops grown and animals reared by such smallholders should fulfil the subsistence as well as the cash needs of smallholders and supplement their cash income from rubber. All these aspects should form part and parcel of the processes in the Dynamic Production Policy. To facilitate and accelerate these processes various subsidies and credits need to be instituted and prudently managed and the profits reinvested for sustained and long-term benefits of rubber smallholders in this country.

STAGES OF DEVELOPMENT AND GOVERNMENT POLICY IN RUBBER SMALLHOLDING AGRICULTURE

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Smallholdings have been a major and dynamic component of the natural rubber industry from its very early years (Table 1). By the 1980's they covered about three quarters of total world rubber lands, and contributed over two thirds of total output. The balance of area and output came mainly from large estates (footnote 1). This great expansion of smallholdings contributed significantly to economic growth in the main producing countries, and gave an important source of cash income to participating farmers.

In light of this vigorous advance, it is somewhat paradoxical that the economic viability of rubber smallholdings has often been underestimated by government. Thus in the early years the burgeoning expansion of their planted area and output surprised the British and Dutch colonial regimes, whose policies generally favoured the estate mode of organisation conducted primarily by their own expatriate nationals. Again in the 1980's, the ability of smallholdings to cope with economic change is widely questioned in official circles (Malaysian Rubber Research and Development Board, 1983 ; Mubyarto, 1983), and improvement policies frequently assume an estate type of organisation to be superior.

The approach in this paper is to analyse the process of smallholding growth over time by Stages, beginning with the initial Stage of expansion into rubber from a basically subsistence economy, and proceeding to the final Stage of rubber in a highly commercialised environment including substantial manufacturing and services sectors. The factors effecting economic growth and smallholder welfare at each Stage are investigated, and the main government policies impinging on these developments reviewed. An attempt is made to identify policies chiefly responsible for facilitating or impeding growth.

The assessment resulting from this process is thought to negate the view of those seeing little future for smallholdings, which appear well capable under appropriate circumstances of adjusting to changed economic conditions. While such adjustment has not always occurred, this may in fact be partly attributed to unsuitable official policies. Given certain policy alterations, it is considered that further dynamic responses of the smallholding sector can be anticipated.

The Stages

The three Stages of development are each characterized by rather different relative endowments of land, labour, capital and other factors, by consequently different prices of these resources, and by a different basic technology. Indeed the latter may itself be regarded as having responded dynamically to price changes since the previous Stage, through the actions of research workers in attempting to improve it in directions economically profitable to the farmers concerned. This is the expected response of technology

Table 1. *World rubber areas, 1900 — 80 ('000 hectares)*[a]

Year	Indonesia Smallh.[c]	Indonesia Estates	Indonesia Total	Malaysia[b] Smallh.	Malaysia[b] Estates	Malaysia[b] Total	Thailand Smallh.	Thailand Estates	Thailand Total	Sri Lanka Smallh.	Sri Lanka Estates	Sri Lanka Total
1900						2						
1910	6	104	110			219						
	109	352	461			883						
1930	729	573	1,302	483	763	1,246						
1940	731	626	1,357	547	843	1,390						
1950				643	795	1,438						
1960				766	783	1,549						
1970				1,077	647	1,724						
1980	1,862	466	2,328	1,206[d]	492	1,698	1,579	46	1,620	122	106	228

Source : International Rubber Study Group (190 — 80) ; sources quoted by Barlow and Drabble (1983).

Notes : (a) This table is incomplete, and contributions of relevant data are welcomed.
(b) Peninsular Malaysia only.
(c) Mainly in the Outer Island of Sumatra.
(d) Including 391,000 hectares under block new planting schemes.

in the induced innovation framework of Hayami and Ruttan (1971), which empirical tests have shown to be broadly correct (footnote 2). The prices of resources and their relative usage by smallholders and estates in producing rubber in each stage distinguished in Malaysia are detailed in Table 2.

Stage I

This is the Stage of emergence from an essentially subsistence agriculture, practiced at the frontiers of cultivation where land is abundant and labour relatively plentiful. The market for capital is both poorly developed and fragmented, and credit thus extremely scarce. Under such circumstances the real prices of land and labour are low, whilst that of capital is very high (Table 2, footnote 3).

Table 2. *Prices, yields and resource use in smallholding and estate rubber production, Malaysia, Stages I, II, and III (prices and costs all in 1978 M$)*[a]

	Stage I (1922)	Stage II (1964)	Stage III (1981)
Smallholdings			
Prices			
Rubber (M$/kg, f.o.b.) b	1·50	2·58	1·80
Land (M$/1ha)	904	3,872	13,000
Labour (M$/day, all in)	4·52 c	7·74 c	11·66 d
Capital (per cent)	30 — 40 e	25 — 30	15 — 20
Wage : interest rate ratio	12·9	28·1	66·7
Yield (kg/tapped ha, all grades)	518 f	1,173	1,300
Resource use			
Labour (M$/ha)	518 f (97) h	1,478 (82)	1,166 (85)
Capital (M$/ha) g	18 (3)	315 (18)	205 (15)
Total (M$/ha)	536 f	1,793	1,371
Total unit costs (M$/1000 kg/ha)	1,035 f	1,529	1,055
Physical labour (man days/a1000kg/ha)	222 f	163	77
Estates		(1963)	
Prices			
Rubber (M$/kg, f.o.b.) b	1·87	2·72	1·92
Capital (per unit)	6 — 7	8 — 10	12 — 15
Yield (kg/tapped ha, all grades)	300	1,308	1,450
Resource Use			
Labour (M$/ha)	638(58) h	1,082(65)	1,057(60)
Management (M$/ha)	259(24)	192(11)	229(13)
Capital (M$/ha)	193(18)	398(24)	476(27)
Total	1,090	1,672	1,762
Total unit costs (M$/1000kg/ha)	3,633	1,278	1,215 k
Physical labour (man days/1000kg/ha)	503	108	62

(Continued over)

(Table 2 *Continued*)

Sources : (of date for 1922 and 1963/64) : sources quoted by Barlow and Jayasuriya (forthcoming)
(of data for 1981) : sources quoted by Barlow (1984).

Notes : a. For "progressive" smallholdings and estates (which account for somewhat over one half of the total smallholding area and two thirds of the total estate area). To convert figures to 1978 P, nominal values are weighted according to an especially constructed consumer price index with 1978 = 100, 1922 = 16·6, 1963 = 58·8, 1964 = 58·1 and 1981 = 130 (for sources, see above).

b. For the balance of grades reported from smallholding/estate rubber output.

c. Returns to tappers getting 50% of the crop at the yields shown, at concurrent task sizes, and at relevant farm gate prices.

d. Valuing smallholding labour at the same rate as estate labour (average 1981 estate earnings per day, plus 20% for perquisites).

e. Nominal, not real interest rate.

f. South Sumatran physical inputs and outputs for 1981, valued at Malaysian smallholding prices for 1922. No physical input figures were recorded for Malaysian smallholdings in the early 1920's, but the basic technology of smallholding production in South Sumatra of the 1980's, was the same. Technical efficiency could well have increased since that time, however, and absolute inputs of labour in 1922 could have been considerably higher than indicated (see also footnote 4). Physical output figures from other sources however, confirm yields somewhat above 500 kg/tapped hectare.

g. All labour, including any management input involved.

h. Figures in brackets are percents of total resource cost in each category.

i. Costs of material inputs (fertilizers, agrocides, transport, etc), which may be regarded as capital. The costs of developing young rubber to maturity are not included.

j. Prices of labour and land were very similar to those for smallholdings.

k. Although unit costs on estates in 1981 were higher than on smallholdings, the unit value of rubber output was also higher (see f.o.b. rubber prices), so that net profit differed little.

The technology of clearing jungle or scrub and of subsequent maintenance depends on simple hand tools, and the technology of rubber production centres on unimproved seed obtained free from neighbouring estates, or cheaply from itinerant traders. These technologies are actually well adapted to the ruling situation of plentiful labour and land. They are also divisible in nature, being applicable on a very small scale and further exhibiting no economies, as scale increases. There is thus little difference in their cost or profit between large and small units (footnote 4). The circumstances of this Stage I production phase are also such that the smallholder response to economic stimuli can be primarily endogenous, with no vital need for exogenous help as occurs in Stages II and III. While there are substantial economies of scale in the end-processing of rubber into various crepes and other products, these are secured through the medium to large scale processing factories set up by the private trading network, and juxtaposing effectively with the smallholding production sector.

Small wonder that with a cash cropping technology so well suited to their conditions, smallholders with their high marginal utility of cash took up the rubber cultivation technology first introduced by the estates with such enthusiasm, and expanded so dynamically (Table 1). The actual conditions of this cultivation varied somewhat, there being on the one hand the extremely land-using and capital-saving operations characteristic of the Indonesian Outer Islands, where land was virtually free and farmers fitted rubber cultivation into a swidden agriculture which still involved the cultivation of subsistence crops (Whitford, 1931). There was on the other hand the somewhat less land-using and capital-saving system true of smallholdings in early Malaysia, where land alienation was more restricted and Chinese smallholding families in particular often earned cash wages which enabled limited material purchases. The predominantly labour-using balance of resource use in production under the Stage I technology is indicated in Table 2. The early Sri Lankan smallholding advance was similar to that in Malaysia, while the rather later Thai development parallelled that in Indonesia.

Under all these conditions however, and also indeed under the more management and capital-intensive circumstances of the estates (Table 2), the yields per tapped hectare and economic returns to the major factors employed were quite similar (Barlow 1978, footnote 4). Thus in writing of the circumstances of the time, de Silva (1982) aptly commented that " largeness in the scale of plantation operations is not an agronomic necessity ; plantation crops can be grown just as efficiently on smallholdings". In fact, during the Great Depression of the 1930's it became apparent that the huge areas of Outer Islands smallholdings with their low fixed costs and alternative subsistence activities were more economically viable than the corporate estates, to which they now posed a distinct threat (Bauer, 1948 ; Thee, 1977).

Stage II

In this Stage substantial commercialization of the economy has occurred, although agriculture is still the dominant economic sector. With the growth of population and of competing demands upon them, both land and labour have become scarcer and therefore more expensive. This same process, however, has reduced the previous fragmentation of the capital market, and credit has become cheaper. The roads and other basic infrastructures of rural areas have been considerably enhanced, especially reducing the cost of transport but also improving information flows.

Much progress has also been made in modifying rubber technology, which has now moved from its primitive first stratum (footnote 5) to a second stratum involving mechanized techniques for land clearing and much higher yielding planting materials responding positively to fertilizers in the phase of production. More sophisticated processing methods have also been developed. This modified technology reflects changed resource endowments in saving land and labour, and making greater use of capital. It also involves considerably more skill in effective application, and is thus management-using. The changed prices and resource use under this modified technology are again illustrated in Table 2.

Yet while this second stratum technology is still divisible in that mechanized techniques can be applied on small units through contract services, while all other maintenance and production components can be employed by farmers themselves on a very small scale, some major problems of adjustment to it have emerged. Thus although the advance through replanting or even newplanting into the higher level technology is usually a profitable long term investment for him, the smallholder does not have the cash needed to hire contract services for clearing, or to purchase the high yielding materials and their complementary material inputs (footnote 6). The private capital market, while better developed then before, is still nowhere near providing long term credit of this nature.

In such circumstances smallholdings cannot advance without exogenous financial support supplied by government. In contrast, however, there is little problem for smallholdings in adjusting to better processing technology, which is easily undertaken by large scale firms with ample capital resources in the juxtaposed rubber trading network.

In this situation the move of farmers in Stage II to a more appropriate production technology depends not only on resource price changes and technological development, but also on exogenously provided replanting and newplanting grants. These were supplied in Malaysia and Sri Lanka of the 50's, and in Thailand of the 60's (Association of Natural Rubber Producing Countries, 1976). Financial support was not provided in Indonesia until the 1970's, however, and then in a very restricted manner. (Koestono and Gwyer, 1976). Indeed, in the Outer Islands in the 1980's, the vast majority of farmers still use the primitive first stratum technology, albeit with some increase in technical efficiency from earlier years (Barlow and Muharminto, 1982). Yet it should also be added that the move into Stage II of relative resource endowments in this remote region has even now not been completed. In many areas land is still quite abundant although at increasing distances from rivers and roads, and in the absence of alternative enterprises most farmers have profitably continued to expand with the old technology in their traditional land-using manner.

It should further be noted that in Stage II the situation of rubber estates differs from that of smallholdings, in that the access of the former to adequate finance generally renders an endogenous adjustment to new technology through replanting quite possible (footnote 7). The estates have a further endogenous advantage in that their management structure enables them to apply new technologies efficiently at field level without outside advice. These features are pecuniary and management economies of scale, which were not relevant with the first stratum technology. Yet given suitable endogenous support, the rubber smallholding in this stage can still adjust well and remain very economically viable, as demonstrated in all countries where official replanting grants and advice have been supplied.

Stage III

In this stage commercialisation of the economy has advanced much further. Agriculture is no longer dominant, being increasingly dwarfed by manufacturing, services, and other sectors. The prices of land and labour have again advanced rapidly, the latter being accompanied by widespread migration from rural areas to what are often more remunerative urban occupations. The cost of capital however, has continued its downward trend. Infrastructures are further improved, and rising levels of general education in particular have both demanded a much improved flow of information and imparted superior ability to assess it. This is really the stage of "industrial revolution", and amongst natural rubber producing countries has so far only been reached by Malaysia.

Technology has once more responded to the changed resource endowment, although in reflection of diminishing returns its savings of scarce resources and additions to yield are not so dramatic as between Stages I and II. Bigger machines for clearing have been developed, and chemical and fertilizer imputs have been improved. Somewhat higher yielding varieties with other desirable attributes have been introduced, and methods of processing have been enhanced. The bias of technology is again land and labour-saving and capital-using, with a further management-using element. The prices and resource use in Stage III are once more detailed in Table 2.

In this Stage, and despite the further development of the capital market, smallholders still require exogenous financial support in moving to renew their productive stock of trees through replanting. It is also very evident, although there were already signs of this in Stage II, that the management skills to apply improved technology effectively are only possessed by some more progressive smallholders. The balance of farmers cannot really manage the technology, and in their consequent failure to replant face a situation of low and diminishing returns. Most members of such less progressive families find they can secure higher earnings from unskilled employment in the modern sector, and in what is a major feature of such a commercialising economy accordingly abandon their holdings in favour of this alternative. It is further evident from Malaysian experience of this Stage that with the rising wage of labour, landowners no longer find it profitable to employ hired workers to tap their holdings for them. While the institution of sharing has proved flexible to change in other contexts (Chew,1981), this particular situation with its tightening labour market appears to contain very real difficulties of adjustment to a more dynamic system (footnote 8) ; substantial areas of holdings run by owner-employers of workers have accordingly been closed down. In Malaysia of the 1980's, perhaps half of the individual smallholding area of 800,000 hectares is owned by less progressive farmers or small landlords, and considerable abandonment of rubber production in this portion has already taken place (Malaysian Rubber Research and Development Board, 1983).

Against this, however, progressive and well informed owner occupying smallholders making regular usage of replanting grants have been earning returns per day from rubber easily commensurate with those from alternative enterprises (Barlow, 1984). Such families rarely earn all their income from rubber, however, since their planted areas are too small for this. Thus in another important feature usually parallelled in other commercialising agricultural economies (Shand,1983), and departing from that of the rather more specialist farms of Stages I and II, they usually have several distinct income sources including some of a non-agricultural nature. Such dovetailing of rubber with other activities not only stabilizes income, but also improves cash flow and enables further purchases of complementary and labour-substituting inputs in rubber production. Yet while the more dynamic elements of this progressive group might also be expected to expand on to the failing and abandoned rubber areas of less progressive elements and small landlords, in a process characteristic of agricultural development elsewhere, the constraints on land transfer outlined below make widespread change of this kind impossible.

Once more the marketing and processing network in Stage III has adapted well to further economic change, undertaking further capital-intensive and labour-using innovations coupled with quality improvements. The estate rubber sector has again continued to thrive in this changed environment, although its comparative advantages with lower interest rates and better information have declined with external economies in these items promoted by commercialisation.

Government policies

The progression of rubber smallholdings through the three Stages has been substantially influenced by various government policies. The most major of these policies are now examined, and their effects on economic growth and the welfare of smallholders assessed.

Research and extension

The provision of rubber research facilities may be regarded as one of the most economically beneficial measures taken by government in all rubber producing countries (Pee, 1977). It is manifestly impossible for individual small farmers to undertake substantial generation of new technology themselves, and in these circumstances government intervention is the best means of bridging the private-social divergence (footnote 9). The early work of Thomas Ridley, the subsequent efforts of Dutch scientists in Indonesia, and the postwar efforts of researchers in the publicly funded institutes of the main rubber producing countries have all made important contributions to more economic rubber production, through enabling a steady improvement in output and quality, with major concomitant savings in usage of scarcer resources (Table 2).

There is nonetheless evidence that especially in earlier research pertinent to the transition from Stage I to Stage II, there was some prejudice toward the relative resource endowment of estates with their lower price of capital. The technology generated at that time consequently had a more marked capital-using bias than was appropriate for the economic position of smallholdings, and appears to have reduced the profitability of their transition to Stage II technology in Malaysia (Barlow and Jayasuriya, forthcoming). While this Stage is past in Malaysia, whose prices now dictate similar technology for both rubber sectors, it is suspected that a similar bias operates against Indonesian smallholdings, which are only now facing the need for transition to Stage II. In that context there is a weighty economic argument for generating a more capital-saving technology specific to smallholding conditions (Barlow and Muharminto, 1982). Again in the current Stage III situation of Malaysia, there are good arguments for further concentrating on labour-saving technology, so as to maintain profitability in face of expected increases in the real price of labour. These arguments apart, there is certainly a well justified case for further heavy emphasis on supporting public rubber research.

The bringing of research technology to the notice of farmers through advisory services is another well justified public activity, especially pertinent in the poorly developed information situation of transition to Stage II, and particularly complementing the crucial process of first replanting with high yielding materials. Despite its obvious importance, however, it is very hard to organize. Except in the notably successful recent case of Thailand, where an effective programme concentrating on crucial aspects of technology transfer in Stage II appears to have been successfully mounted (Phit Panyalakshaña and Blencowe, 1976), such extension has rarely had very wide impact. Thus in Indonesia in the late 1970's, rubber extension hardly existed outside the intensive rubber development schemes (Barlow and Muharminto, 1982). In Malaysia the recent social emphasis of extension, together with its focus on restricted groups, has meant that relatively few rubber farmers have had much assistance in adopting new technology (Malaysian Rubber Research Development Board, 1983). More broadly directed and technically oriented extension in these contexts can undoubtedly assist adoption, and is thus most desirable.

Replanting grants

The exogenous organisation by government of replanting grants has been of vital economic significance enabling independent smallholders to make a lumpy investment in higher yielding materials. The provision through an export tax transfer mechanism of necessary material inputs in cash or kind, together with additional cash to cover the cost of labour inputs (footnote 10), has successfully bridged the private-social divergence attributed to imperfect capital markets, which even in Malaysia of Stage III are not sufficiently developed to provide credit for such a purpose. This approach to funding small plantation investment has great advantages in following what we have previously termed a "dispersal" strategy (Barlow and Jayasuriya, 1984). In contrast to the more specific and locationally concentrated situation of the land development schemes discussed below, it is available to all progressive elements throughout the farming community, and thus has maximum economic impact (footnote 11).

As already mentioned, the economic benefits of replanting grant programmes have been amply demonstrated in all major natural rubber producing countries except Indonesia. It is strongly felt that where it is economically desirable, existing programmes should be maintained and new programmes extended into untouched areas, although the coverage of the measures must naturally depend on what material resources are available. Thus in contrast to the liberally funded programmes of Malaysia, Indonesia and Thailand, Barlow and Muharminto (1982) in the Indonesian context have suggested very restricted planting assistance, largely comprising selected seedling planting materials accompanied by advisory help in establishing them. Such materials are regarded as a "minimum technological base", which is then susceptible to further improvement through other complementary inputs as more cash becomes available.

Difficulties have of course emerged in all replanting grant programmes, and basically concern the failure of less progressive farmers to make use of this investment opportunity. In Stage II where there are normally no major alternatives to rubber cultivation, these are best dealt with by special follow-up measures to assist adjustment (footnote 12). In Stage III they are better handled through freeing the land market in the manner, discussed below, together with direct training and other assistance to facilitate the transfer of persons who cannot benefit to urban areas.

Land use regulation

This has been applied in most rubber producing areas since the beginning of Stage I, normally with some form of social or political justification.

Thus the colonial government of early British Malaysia employed what de Silva (1982) has termed "legal-institutional barriers" to reduce the Stage I smallholding expansion on to land suitable for estates and in Dutch Indonesia even more rigid measures effectively banished smallholding development to remote peripheries in the Outer Islands (Geertz, 1953). On the other hand, the further land use measure in Malaysia of reserving wide areas for Malays only under the Malay Reservations Enactment of 1913 did at least have the merit of preserving for indigenous peoples a major stake in the rubber economy of their own land. Another practice during the early colonial period was the reservation of land titles for particular crops only, and this was again largely applied against smallholding interests to reduce their rubber cultivation in competition with estates (Lim, 1977).

But the subsequent persistence of these regulations, often with significant political overtones, has usually had adverse long term effects in " locking " farmers in to economic activity not desirable in a dynamically changing economy. Thus the location of most Indonesian rubber smallholders in remote areas with few linkages to a wider economy has made their desirable transition from Stage I to Stage II that much more difficult. The existence in Malaysia of reservations and the specified cultivation of certain crops, together with bureaucratic difficulties in land transfers have rendered far harder the conversion of lands to more economic purposes. Such conversions notably concern the sale of abandoned rubber lands to more progressive smallholders. Especially in Stage III with its much wider economic alternatives including wage employment in the urban sector, there is little justification for preserving the position of particular groups in agriculture through such regulations.

It is accordingly believed that as development proceeds, the manifold land use regulations in rubber smallholding sectors should carefully assessed, with a view to removing what are in fact serious constraints on more economic operation and long term smallholder welfare.

Land development schemes

From the late 1950's in what was essentially the transition to Stage II, the newly independent government of Malaysia commenced a substantial policy of organizing rubber improvement through new group land development schemes. In contrast to the " dispersed " policy of replanting grants, new planting in these schemes was focussed on contiguous blocks of individual settler parcels, organized in several ways. These ranged from small schemes of up to a few hundred hectares, with relatively loose guidance by management and no ancillary services or special infrastructures, to generally very large schemes of one thousand or more hectares with tight management, central processing and other facilities, and well developed infrastructures including settler housing (Lim, 1976) (footnote 13). The latter case was epitomized by the great schemes of the Federal Land Development Authority, whose concept was one of arranging management and services so as to secure economies of scale in these items, while at the same time retaining quasi-independent settler units for the production phase. Indeed, the institutional principle of such schemes may be described as that of a " guided yeomanry ", planned as combining the advantages of central supervision and certain other facilities at the top with independence at the bottom (footnote 14).

All the early land development schemes were launched in a situation of widespread landlessness within cultivated areas, where an official investment of capital to improve previously inaccessible land appeared both socially and privately profitable. Such schemes were often favoured by government over dispersed development, owing to their greater visibility and apparent amenability to central control.

Yet almost from the beginning, the smaller less organised schemes encountered mounting problems arising from uneven development. Commonly they emerged as a patchwork, with all too many bad parcels interspersed amongst good in direct reflection of the differing motivations and abilities of participating farmers. In contrast to this, the large coordinated schemes of the early years appeared to be developing well, and indeed to justify their far more elaborate nature and intensive supervision. Their approach was accordingly emphasized further in new developments (footnote 15).

Then during the 70's the large schemes too entered a period of increasing trouble, partly owing to the wider developments of Stage III. Thus the departure of younger people left an ageing population, increasingly unable to exploit their parcels efficiently. There was also, however, an emerging conflict between settlers and management, where the former appeared to regard their individually allocated blocks as their own to be managed as they wished, especially where they had substantially repaid their debts (footnote 16). Management, on the other hand, continued to press for certain husbandry practices which the settlers were not prepared to accept (footnote 17). This conflict undermined the whole process of technology transfer, leading to lower than expected incomes and thus to a further acceleration in departure of the younger people. Yet under the prevailing tenure arrangements of these schemes, it was again not possible for progressive elements to expand their activities through purchase of adjoining parcels. Thus there was once more a prospect of settlers being locked into a situation of declining productivity, with economic returns much below those originally anticipated. It was largely owing to this that the recent group reviewing Malaysian rubber policies recommended that " all new land schemes should from now on be operated as commercial estate enterprises ", and that the individual parcel concept be abandoned (Malaysian Rubber Research and Development Board, 1983).

While Indonesia, as the only other country with major group rubber land developments, did not begin these substantially until the mid 1970's, similar problems of uneven progress have already appeared in smaller less coordinated schemes, and been countered by more intensive supervision (World Bank, 1974 — 82). On the other hand the large co-ordinated " nucleus estate " schemes of Indonesia, which are now the preferred official method of smallholding development (Mubyarto, 1982), have barely reached the production phase, and thus not faced any real problems in settler-management relations (footnote 18). Again the lack of alternatives to rubber in the Indonesian Outer Islands, where Stage II has hardly begun, means that outmigration will not be a difficulty in the near future.

Yet the problems of uneven development and management relations would already seem quite widespread enough to raise serious questions about the long term viability of group land development schemes as an institutional mode of smallholding improvement, especially in the more commercialized environment of Stage III. While governments recognizing these difficulties may thus be predisposed to recommend the replacement of this mode by estates, preferably under the auspices of some government instrumentality (footnote 19), the latter condition especially should also be questioned. This is in a situation where the role of government in directly administering development may already be seen as overextended and counter productive.

The commercial estate development of new land is certainly one solution, where this is economically desirable. Another alternative is the opening up of such land by independent smallholdings. Given suitable exogenous support, with flexibility for expansion or contraction of units according to economic circumstances, this would seem at least as viable an economic approach which could have important social advantages (footnote 20).

Marketing improvement

One sphere of active government intervention in all countries has been that of domestic rubber marketing. This reflects a widespread suspicion by all sections of the community, including some academics (e.g., Wharton, 1962), that pricing is manipulated by various middlemen to their own benefit in excess profits, and to the farmers' detriment in lower prices. Such suspicion has arisen despite the fact that the trading network generally seems to have adjusted quite efficiently to resource price and technology changes at successive Stages.

Although some " imperfections " in the domestic market undoubtedly exist, it is our impression that widespread exploitation of this nature has yet to be substantiated through rigorous empirical study (Lim, 1968). Thus the trading network in most countries appears to include sufficient competitive elements to prevent monopsonistic behaviour. It might also be hypothesized that the degree of exploitation would be greatest in Stage I, where the market for rubber products may be seen as most fragmented, with little price information reaching producers. Even in this stage, however, it is apparent that except in remote places with small rubber areas which barely support one dealer the trading network is generally quite competitive (footnote 21).

Certainly it also seems fair to comment that the manifold efforts made by government in all rubber producing countries have rarely had much positive influence on the farm gate rubber price. In most cases, government market intervention has been effected at considerable cost in scarce managerial resources, and following expensive mistakes over a period of several years has usually been withdrawn (Thomas, 1957 ; Barlow and Lim, 1965; Abdullah *et al*, 1972). In instances where government agencies have been granted some monopoly, it appears that farm prices have actually been depressed below levels which would otherwise have obtained in the " free " (albeit imperfect) market without such intervention (Thomas and Panglaykim, 1973). The most successful interventions over the years appear to have been those aiming to improve quality through small local " group processing centres " (Sribo Chaiprisit and Lim, 1976), although even in this case the primary continuing role has actually been taken by centres sponsored under private rather that government auspices (Barlow, 1978).

Intervention in domestic marketing is thus regarded as a normally expensive measure, justified increasingly less as development proceeds into Stage III and deserving very careful prior assessment. Where it is thought warranted, the low cost alternative of attempting through appropriate measures to push the private sector towards greater competitiveness without expensive direct intervention should certainly be considered (footnote 22). Quite often indeed, much can be done by abolishing such constraints as licencing provisions on private dealers, which effectively bolster their position by preventing the free entry of other competitors into the market. Certainly as a rubber economy moves into the commercialized environment of Stage III, direct intervention is rarely likely to be worthwhile.

Governments have also intervened in the international marketing of rubber, notable in the Stevenson and International Rubber Regulation Agreements of the 1920's and 1930's to restrict the supply of rubber, and in the International Natural Rubber Agreement of 1979 to iron out price fluctuations. The adverse long-term influence of output restrictions in reducing the competitiveness of natural rubber, and the discriminatory application of such restrictions to smallholdings, have already been well established (Bauer, 1948 ; Lim, 1977). While the current international buffer stock scheme is particularly helpful to smallholdings to the extent that it reduces price fluctuations, the price of achieving this goal must also be weighed against alternative more direct means of stabilization (footnote 23).

General measures

One major group of more general economic measures concerns improvements to infrastructures, and especially to roads and other communications. While progress in this aspect to some extent parallels the Stages of rubber development, there have been considerable differences between countries within given Stages. Thus there was a large contrast in Stage I between the almost unserviced rubber growing regions of the Outer Islands, and the much better infrastructures accompanying and helping to explain the faster early growth of smallholding rubber planting in Malaysia and Sri Lanka. Again, the special emphasis on infrastructural improvement in Malaysia of the late 1950's and early 1960's much assisted the wide early success of replanting and other rubber improvement measures in that country (Ness, 1967).

Infrastructural investment promotes major external economies in rubber production, most notably in lowering transport costs, but also in a range of associated aspects already mentioned as accompanying commercialization. Substantial emphasis on such investment by government is accordingly favoured as a further major way of promoting smallholding advance.

The other major group of overall economic measures effecting rubber essentially comprise fiscal policies. These involve taxes on agricultural exportables including rubber, together with exchange rates, import duties, quotas, and price supports directly intended to improve the profitability of manufactured goods and food crops. Heavy taxes were quite justifiably applied to rubber in Stage I and early Stage II, when it was major amongst export items and one of the few sources of income to government, but their continuation during the later part of Stage II and in Stage III, when rubber is usually a declining industry should be seriously questioned (footnote 24). Indeed, we believe we have already demonstrated in our companion paper (Jayasuriya and Barlow, 1984) the undesirable implications for the whole economy of the fiscal measures towards rubber in Stage II of Sri Lanka. It is thus believed that fiscal policies towards rubber and other agricultural exportables should be carefully reassessed, especially in light of the generally poor economic performance of the preferred alternatives, with a view to removing what appear to be very serious distortions in several national economies.

CONCLUSIONS

The great expansion of rubber smallholdings over the first 80 years of this century illustrates the capacity of small farmers and the rural trading network which serves them to respond dynamically to appropriate economic incentives. This development may be usefully characterized into three distinct Stages, which have implications for the nature of development taking place. During this development towards commercialization, land and labour become increasingly scarcer and capital relatively cheaper, while the nature of technology basically follows this change in resource relationships. It is thought somewhat paradoxical that despite illustrating their capacity for change, smallholdings have generally been underrated by governments, which have looked to the estate model as a more suitable form for any development or expansion.

The argument in this paper is in part that of neoclassical free market economist, but it goes further than this. Thus on the one hand it is felt that particularly with the move into the full commercialization of Stage III, more rein must be given to the great potential of the progressive small farmer element. This can partly be done by removing various distorting measures of government which constrain this element, and at the same time seriously reduce the capacity of the rubber sector as a whole to respond to economic change.

These distorting measures, which may at one time have had good political or social justification, include regulations on land use, inflexible institutional forms of land development, costly interventions in marketing, and various fiscal policies serving to stimulate other sectors at the expense of rubber and other prime exportables.

It is also recognized, however, that the smallholding sector is inherently not able to respond to economic change without exogenous help, and requires strong positive assistance by government in certain key spheres. These comprise research and extension, planting grants, and infrastructures, all of which are probably most crucial in enabling the transition from Stage I to Stage II, but remain necessary in some degree as commercialisation of the economy continues. Removing expensive and unnecessary government intervention in other spheres should enable these positive aspects of intervention to be more effectively undertaken.

It is believed that given a re-orientation of policies in the manner suggested, a much more vigorous smallholding response to change can be expected, including a more rapid transition to more advanced Stages in the different natural rubber producing countries.

FOOTNOTES

1. Most were corporately or publicly organized, and covered well over 1,000 hectares. There was also a minority of smaller proprietary concerns (Barlow, 1978).

2. Thus the resource-using bias of new technologies will match the relative prices of these resources to farmers.

3. In a subsistence agriculture there is little demand for capital, and thus no proper market for it. In contrast, the estate sector of the early natural rubber industry had access to the highly developed stock markets of Europe.

4. Although the resource cost in producing rubber on smallholdings Stage I is shown as being far lower than that on estates (Table 2), the smallholding figures actually refer to South Sumatra in 1981, by which time there had probably been a substantial increase in technical efficiency, even with the primitive Stage I technology.

The yields on estates in Stage I appear to be somewhat lower than on smallholdings (Table 2), and confirmation of this is provided from other available data (Barlow and Jayasuriya, forthcoming)

5. Technology is somewhat crudely but conveniently regarded here as proceeding to higher more technically and economically efficient levels by successive " strata ", each of which represent the emergence of a new set of innovations (and their underlying production functions). In fact, the progress to higher levels tends to be a continuous affair.

6. Although the production technology itself is divisible, there is considerable lumpiness in the investment in replanting, in that owing to shading and other agronomic problems it is usually not possible to consider the replanting of less than about 0·5 hectares.

7. While various income tax concessions and even direct grant provisions have been made to encourage estates with replanting, it is apparent that they can also undertake replanting investment using their own privately generated funds, or those borrowed on the private capital market (Barlow, 1978).

8. In the tight labour supply situation with their consequent ease of moving to new jobs, workers had short term horizons in particular jobs, and purposively extracted maximum short-run yields from the trees, thereby seriously damaging their future productivity. On the other hands the hierarchical estate arrangemrents which enabled profitable large scale land ownership were not applicable in this small context.

9. Although public facilities were also provided for the estates, this was not really necessary in their case, as demonstrated by the highly successful Dutch cooperative research stations organized by the estate companies (Dijkman, 1951).

10. Thus in most cases replanting (and research) have been financed by a " cess " component of the export tax, which is then placed in a fund to be subsequently disbursed as indicated by a special administering agency (Edwards, 1970 ; Association of Natural Rubber Producing Countries, 1976 ; Booth, 1980).

11. Under these conditions the more progressive farmers, who can be assumed to be the better managers with higher marginal value products to resource investment, will all have the opportunity of securing grants. This contrasts with the locationally concentrated land developments, where a somewhat arbitrarily selected group of farmers containing both good and bad managers receives assistance. The total marginal product to investment will be less in this latter case.

12. Thus replanting grants may be increased for the smallest holdings, which may also receive other direct welfare assistance.

13. In Federal Land Development Authority rubber schemes the settlers arrived about half way through the immaturity period, some time after the initial clearing and planting of land which was undertaken by contractors. They then worked under general supervisors on maintenance activities, and only commenced specific activities on their allocated parcels of about 4 hectares at the start of tapping. In new schemes since 1979, the individual parcel system has been replaced by one of 100 ha blocks, operated by groups of 24 settlers.

14. This principle has been popular and widespread in South and Southeast Asia since the first years of Independence. It is also applied to other plantation crops, and to some giant rice cultivation schemes, such as the Mahaveli in Sri Lanka.

15. As a result of their difficulties, many smaller schemes were taken over and rehabilitated by the Federal Land Consolidation and Development Authority, which managed most of them in a highly centralized fashion using hired tappers.

16. Most land schemes involved the repayment of about two thirds of development costs with interest by participating settlers, usually through deduction of proceeds from latex sales over a period of some 15 years.

17. The husbandry practices put forward by management involved careful conservative exploitation over a long time period, while the settlers generally wished to minimize short term yields. The settlers barely considered the cost of replanting trees, which would be initially undertaken and paid for by the scheme.

18. It was only in the production phase when settlers became actively involved with their parcels that conflicts began to rise. During immaturity the settlers were " newcomers ", and also worked in general gangs rather than on particular parcels.

19. Thus in the case of abandoned individual rubber smallholdings in Malaysia, consolidation and rehabilitation is being organised in "mini-estates" by the Rubber Industry Smallholders Development Authority.

20. In the past the commercial estate system has been associated with the regimentation of workers and their families (Jain, 1970 ; de Silva, 1982).

21. Thus in almost all cases of a sample of 250 rubber smallholders scattered through South Sumatra Province, farmers appeared to have a choice of several possible buyers (Barlow, 1981).

22. Much can be done by supporting the establishment of better central commodity markets, through providing basic facilities etc.

23. Thus these macro-measures of stabilization should be compared with the alternative of direct grants to the poorest farmers, preferably with training and investment components.

24. Rubber in the late 1970's in Malaysia suffered significant negative effective production (Sahathavan Meyanathan and Wells, 1982).

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SESSION 8. ROOT DISEASES

TOWARDS A BETTER LIVING STANDARD OF THE RUBBER SMALLHOLDER

By

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Agriculture in general is the single largest source of employment in Sri Lanka as 43 percent of the economically active population is engaged in it, directly or indirectly.

Rubber, one of the major plantation crops, has contributed significantly to this feature, over the last century. Rubber is a labour intensive crop which has played a very significant role in the economy as it has generated 500,000 employment opportunities, a majority of them in the rural sector. The extent under rubber is 205,700 ha, comprising 20% of the total plantation crops.

Economically, rubber continues to play an important role as the export earnings in 1983 amounted to Rs. 2,852 million.

As in all rubber producing countries, the smallholder sector predominates in Sri Lanka too. The ownership of the smallholder sector which is presently 68% of the total area under rubber rose from 33% as a result of the land reform acts of 1972 and 1975. This area supports nearly 196,000 smallholders (Table 1).

Table 1. *Distribution of rubber land area*

Size group (ha)	Ha	%		Holdings	%	
0 — 0·5	32651	16	48%	130604	67	98%
0·6 — 1·0	31474	15		41965	21	
1·1 — 2·0	21446	10		14297	7	
2·1 — 4·0	14398	7		4800	3	
4·1 — 10·0	19941	10	20%	2849	1	1·7%
10·1 — 20·0	11425	5		761	0·5	
Over 20·0	10043	5		335	0·2	
State	67300	32	32%	n.a.		

Rubber is also an ideal smallholder crop as it is capable of growing under varying conditions of difficult terrain and can withstand different management standards. It also has a flexibility in the scale of production and marketing.

The broad objectives of the institutions involved with the agricultural development is to bring about an increase in family income, generate employment opportunities and improve the general living standard of the population. The role of the Advisory Services Department (ASD) of the Rubber Research Board (RRB), is therefore to achieve these objectives for the rubber smallholder. A multidisciplinary approach has been found to be successful with rubber.

Replanting

Increased rate of replanting on an annual target of 3% of the national stand was a primary objective since the inception of the Rubber Replanting Scheme in 1953. A considerable drop in performance in the early 1970s, to a very low level of 1·0% has resulted in an accumulation of uneconomic rubber to the alarmingly high rate of 28 percent of the national stand in 1979, thus resulting in a very low national average yield in the smallholdings. Replacement of the above with high yielding and disease resistant varieties was considered a priority activity in the eighties.

The smallholder Rubber Rehabilitation Project launched in 1980, under World Bank assistance, has played a vital role and the performance is considered satisfactory, despite climate constraints (See Table 2). Further marked improvement is shown in the new planting rate, which is considered essential in view of the large scale urbanisation and fragmentation of land.

Table 2. *Amount paid as rubber replanting subsidy for private sector*

Amount in Rs. per acre	Date the payment commenced
2000/-	1974 — 1976
3000/-	16th November 1977
4000/-	16th November 1978
5000/-	1st September 1979
6000/-	15th November 1979
7500/-	13th November 1981
9000/-	15th March 1983

Source RCD

The generous subsidies given by Government for both replanting and new planting have encouraged rubber planting. The high yielding, disease resistant clones of the RRIC 100 series have been popular with smallholders. The new nursery unit, has led to proper nursery administration and effective distribution of plants to replanters (Table 2 I).

Table 2 I. *Planting material distribution under S.R.R.P.*

Year	Season	No. of SH	No. of Plants	Acreage
1981	May/June	1779	501,419	2493·2·00
1981	Oct./November	1417	376,538	1853·0·00
Total for 1981		3196	877,957	4346·2·00
1982	May/June	2160	698,000	3209·2·30
1982	Oct./November	1106	312,350	1470·1·37
Total for 1982		3266	1,010,350	4680·0·35
1983	May/June	2369	797,312	3507·0·16
1983	Oct./November	1209	371,012	1643·3·16
Total for 1983		3578	1,168,324	5150·3·32
1984	May/June	2326	697,545	3232·0·05

Fertilizer

The present low yield per unit area has increased the cost of production of smallholdings. In addition, the current high cost of fertilizer almost precludes its use in smallholdings, unless it is given at subsidised rates.

In order to achieve increased usage and also to obtain the best benefits, fertilizer mixtures based on soil series are being distributed as a part of the Smallholder Rubber Rehabilitation Project (Table 2 II). Fertilizer demonstration plots are located in 5 rubber growing districts. Smallholders will also benefit from soil and foliar analysis recommendations.

Table 2 II. *Fertilizer distribution under the S.R.R.P. Kegalle, Kalutara, Ratnapura districts*

Year	Season	No. of SH	Acreage	Quantity distributed Kg.
1981	Aug./Sept.	1980	2923·0·32	73·415
Total for 1981		1980	2923 0·32	73·415
1982	Feb./March	3597	5531·1·00	137·710
	Aug./Sept.	6530	9324·1·16	311·220
Total for 1982		10487	14855·2·16	448·930
1983	Feb./March	7932	11428·2·17	431·930
	Aug./Sept.	10398	15373·3·34	698·415
Total for 1983		18330	25802·2·11	1,130·345
1984	Feb./March	11766	17652·0·37	866·990
	Aug./Sept.	13414	19762·1·15	1,283·210
Total for 1984		25170	37414·2·12	2,150·200

Intercropping

The objective of the smallholder and particularly the smallest, is more to maintain an adequate cash income and to maximize returns per hectare. Intercropping offers the opportunity to do this during the immature period, and is therefore attractive to the smallholder. Although hilly terrain, absentee ownership and, inconsistent marketing conditions present impediments to the efforts made, fair success has been made in promoting perennial and seasonal crops (Table 3).

Table 3. *Smallholder Rubber Rehabilitation Project Intercropping — 1983*

District	Crop	Replanting acreage	Newplanting acreage
Kegalle	Banana	250·1·38	148·1·20
	Vegetable	14·2·20	—
	Pineapple	15·1·00	8·0·00
	Paddy	0·1·00	—
	Coffee	1·1·20	—
	Passion fruit	0·2·00	—
	Others	—	0·3·00
Ratnapura	Banana	92·0·27	46·3·30
	Cocoa	1·2·00	—
	Coffee	0·2·00	—
	Vegetables	5·3·30	—
	Passion fruit	13·3·00	17·2·00
	High land paddy	5·0·00	—
	Pineapple	1·1·00	—
	Others	8·0·00	6·0·00
Kalutara	Banana	126·0·20	6·2·00
	Passion fruit	125·0·38	45·2·26
	Coffee	1·2·00	—
	Pineapple	2·0·00	0·2·00
	Vegetables	84·2·23	4·1·01
	Others	—	2·2·00

The common observation is that rubber grows better whenever intercropping is practised.

Processing and marketing

The Rubber Research Institute (R.R.I.) encourages central collection of smallholder latex for latex based industries, centrifuging plants and to state owned crepe rubber and technically specified rubber factories ; these are of significant benefits to the smallholder. Further, by processing the rubber in large factories, where cost savings are made on scale of production, the country's foreign exchange earnings are enhanced and at the same time a better price is paid to the smallholder. In remote and difficult areas the Advisory Services Department aids in establishing Group Processing Centres (G.P.CC) to process smallholder latex into superior Rubber Smoked Sheets (RSS).

Training

Special emphasis is being given to the aspect of training with a view to achieving better cultivation standards.

Broadly, the training activities offered could be categorised into :—

(a) Foreign training

(b) Resident training (Local)

(c) Field training

Short visits to major rubber producing countries such as Malaysia, Thailand, Indonesia are being made by rubber extension personnel, and this programme is continuing as a part of the Smallholder Rubber Rehabilitation Project. These short programmes have been extremely beneficial in teaching modern concepts, in all aspects of rubber growing, manufacture and marketing.

A fully equipped training centre was established in 1982 to provide resident facilities to the Advisory Services Department staff and all other categories involved in the rubber industry. Induction programmes, and annual refresher programmes to Advisory Services Department staff and smallholder training in cultivation and processing, are broad priorities (Table 4).

Rubber research findings, cultivation standards, intercropping and processing procedures are the main areas of training given. Short programmes covering the areas of paddy cultivation, coconut growing, family health, environment and ecology, and forestry are also provided to enable the extension personnel to be more resourceful at the village level. The centralised training programmes also include training of selected smallholders. Village leaders and selected youth, involved with rubber husbandry are given priority. As an inducement to the smallholders, free board, lodging and transport from their residential areas are provided to them.

The training centre has been extremely useful to other related institutions, such as the Co-operative Department, Sri Lanka State Plantation Corporation (S.L.S.P.C.), Janatha Estate Development Board (JEDB), National Fertilizer Secretariat (NFS) and the Rubber Control Department (RCD) who are involved with the rubber husbandry and marketing. Other government officers who are engaged with rural agricultural development at grass-roots level are also accommodated in the programmes.

In addition several field programmes are regularly conducted by the extension personnel and the objective of these programmes is farmer education and creation of awareness. These include rubber cultivation training programmes for which an approved curriculum is followed by all the Rubber Extension Officers (R.E.OO). Certificates are presented to all successful participants.

Other programmes such as village level group discussions, field days, field demonstrations, are of immense educational value to all involved in the management of rubber.

Table 4. *Progress of training programmes at the training centre established at Nivitigalakele*

Type of Course	Category of participants	No. of Training Programmes held			No. of participants		
		1982	1983	1984	1982	1983	1984
01. Induction Course	Rubber Extension Assistants	01	02	01	16	26	16
02. Induction Course	Rubber Inspectors	—	01	—	—	38	—
03. Refresher Course	Rubber Extension Officers	03	03	03	74	74	74
04. Refresher Course	Rubber Extension Assistants	—	—	01	—	—	16
05. Refresher Course	Divisional Rubber Extension Officers	—	01	01	—	14	16
06. Refresher Course	Senior Processing Advisors/ Processing Advisors	—	—	01	—	—	12
07. Processing Advisory Training	— do —	—	01	—	—	12	—
08. Rubber Husbandry Training	Rubber Smallholders	01	05	08	30	150	240
09. Rubber cultivation	Field Officers (SPC)	—	—	01	—	—	21
10. Rubber Processing Training	Rubber Smallholders/Group Processing Centre's members	—	02	04	—	60	120
11. Rubber Processing	Factory Officers (SPC)	—	—	01	—	—	19
12. Rubber Cultivation & Processing	Co-operative Managers	—	06	—	—	150	—
13. Fertilizer Demonstration Training	All Rubber Extension Officers (Kalutara District)	—	—	01	—	—	35

Publicity

Active publicity has been an important component in the Advisory Services Department, throughout the years. Activities covered are :

(a) Programmes conducted with the national television network and the radio.

(b) Press publicity by way of news, articles and advertisements,

(c) Publicity material — posters, leaflets and hand-outs,

(d) Field programmes such as field days, demonstrations, group discussions and village-level seminars,

(e) Participation in exhibitions and competitions,

(f) Village-level cinema programmes,

(g) Participating in joint community programmes with the other institutions.

Considering the increased demands and challenges of the smallholder sector, the Advisory Services Department (ASD) has made a conscientious effort to strengthen its services during recent times. This includes functional decentralisation, strengthening of the staff and the provision of necessary infrastructure. Smallholder Rubber Rehabilitation Project is very helpful in obtaining the desired results having taken into consideration the benefits realised by the smallholder. The World Bank has recognised the work done by extending the project to all the rubber growing areas of the country.

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SOCIO-ECONOMIC CHARACTERISTICS OF RUBBER SMALLHOLDERS IN SRI LANKA : IMPLICATIONS FOR DEVELOPMENT

By

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INTRODUCTION

The rubber industry occupies an important place in the economy of Sri Lanka. The total rubber area was estimated to be 476051 acres or 192655 hectares in 1979 representing 20 percent of the total area under main plantation crops (CDC, 1979, vol. V. APP. 1). About 349203 acres or 68 percent of this area is owned by private rubber growers and 48 percent of them are smallholders owing less than 4 hectares each. The rubber industry has provided employment for nearly 500,000 persons both directly and indirectly in the 195,600 rubber holdings and in various stages of processing upto shipment.

The rubber industry is classified into the estate sector and the smallholding sector. According to the original classification adopted by the Rubber Controller, lands below 10 acres are classified as smallholdings and the lands above 10 acres to below 50 acres are classified as private estates. The smallholder Rubber Rehabilitation Project of the World Bank which sought to improve the smallholder rubber sector classified all rubber lands below 50 acre to be small holdings.

Much of the rubber is now old and there is a need to improve the efficiency of the industry by increasing the rate of replanting with new technologies and also accepted management practices. The various policies and incentives offered with pious intent, manifestly failed to arrest a general deterioration of the industry. This is particularly so in respect of replanting. The structure and the problems of smallholders and estates differ significantly. It is an imperative to understand the structure and functioning of the smallholders and estates to establish effective policies. The objectives of this paper are : (a) to document some of the main socio-economic characteristics of rubber smallholders in Sri Lanka, and (b) to draw implications of these characteristics for their development.

METHOD OF STUDY

This study is based mainly on a socio-economic study conducted by the authors in three rubber growing districts in Sri Lanka, namely: the Ratnapura, Kalutara and Kegalle Districts. These three areas represent the best rubber growing areas in the country accounting for 68 percent of the country's rubber acreage. Three hundred smallholders from each of the three districts were selected according to a two stage random sample. The information required for this study was collected mainly from those 900 smallholders

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through detailed interviews. Information relating to household particulars, land use pattern, income profile, production and processing patterns in rubber are collected during the survey. These are discussed in the sections to follow.

Socio-Economic characteristics

Demographic characteristics and educational status

The survey showed that the average size of the household is 5·8, 5·3 and 6·1 persons for the Ratnapura, Kalutara and Kegalle Districts respectively. Approximately 54·3, 49·5 and 51·9 percent of the smallholder population in the Ratnapura, Kalutara and Kegalle Districts are males. A majority of them in all three districts is in the economically active age group of 15—64 years. The economically active group constitutes 69·9, 68·6 and 71·2 percent of the total population for the Ratnapura, Kalutara and Kegalle Districts, respectively.

The literacy rates among the farmers in (aged 5 years and over) Ratnapura, Kalutara and Kegalle Districts are 94·8, 96·7 and 96·8 percent, respectively, which is very high. However, the literacy rates among females in all three districts are slightly lower than those of males. There is also a marked variation in the educational attainments of the population. Majority of the population in the three districts had an educational level of I — IX. This group constituted 72·2, 70·6 and 65·2 percent in the Ratnapura, Kalutara and Kegalle Districts, respectively. The percentages of those who have had education upto General Certificate of Education (Ordinary Level) are 14·0, 19·9 and 23·9 in the Ratnapura, Kalutara and Kegalle Districts, respectively. The number of people with higher qualifications (GCE A/L) and above ranged from 3·4 percent to 6·3 percent.

Activities and characteristics of the labour force

The activities of the smallholder rubber farmers are an important aspect in designing policies for them. Information relating to their activities is given in Table 1.

Table 1. *Distribution of the sample population by main activity (percentage)*

Activity	Ratnapura	Kalutara	Kegalle
Employed*	28·8	29·5	26·5
Unemployed	10·0	11·8	14·4
Family helpers	6·4	5·0	4·5
Housewives	13·4	14·4	13·4
Students	25·4	21·4	28·4
Others*	15·2	17·9	12·8
Total	100·0	100·0	100·0

* Including employed children
Source : Jayasena, W. G. and Herath, H. M. G. (1984)

Table 1 shows that the employed and student categories form the important activity groups in all three districts. The employed category comprises 28·8, 29·5 and 26·5 percent in the Ratnapura, Kalutara and Kegalle Districts, respectively. The other two important activity categories are the family helpers and housewives which together constitute 19·8, 19·4 and 17·9 percent of the total of the sample population in the Ratnapura, Kalutara and Kegalle Districts, respectively.

The distribution of the labour force into the five main activity groups referred to earlier is given in Table 2.

Table 2. *Percentage distribution of labour force in the sample by activity*

Activity	Ratnapura			Kalutara			Kegalle		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Employed*	33·3	7·2	40·5	34·0	8·3	42·3	32·6	4·2	36·8
Unemployed	7·7	7·7	15·5	6·9	10·3	17·2	9·9	10·5	20·4
Family helpers	3·0	6·3	9·3	0·6	6·7	7·3	0·6	5·7	6·3
Housewives	—	19·4	19·4	—	21·0	21·0	—	19·1	19·1
Students**	7·9	7·4	15·3	5·7	6·5	12·2	8·9	8·5	17·4

* Excluding employed children

** Students aged 15 years and over

Source : Jayasena, W. G. and Herath, H. M. G. (1984)

The economically active population of the Ratnapura, Kalutara and Kegalle Districts are 85, 87 and 83 percent, respectively. The employed population in Ratnapura, Kalutara and Kegalle are 40·5, 42·3 and 36·8 percent, respectively. Majority of the employed in all three districts are males. Another important feature of the labour force is the high level of unemployment in the three districts. The unemployed population is 15·5, 17·2 and 20·4 percent in the Ratnapura, Kalutara and Kegalle Districts, respectively. Family helpers are also fairly high in all three districts. Though they do not engage in any gainful employment, the services given by them for their family activities for rubber production especially tapping are important. The housewives population is also very high and in most smallholder families, the tapping and processing activities in rubber are done by the housewives, a part of their day to day activities.

The employment pattern amongst the smallholder rubber farmers according to occupation is given in Table 3. Table 3 shows that 51·6, 50·5 and 41·6 percent of the farmers in the Ratnapura, Kalutara and Kegalle Districts are employed in agriculture. Thus agriculture is the single largest source of employment and income for most farmers in the study area. The second important source of employment is government service which is classified here as ' white collar ' jobs. The white collar category is high in Kalutara amounting to 31·6 percent. This is due to the closeness to Colombo and the easy accessibility. Petty trading and non-agricultural labour are also important sources of employment. A special feature of the Ratnapura District is the importance of the gem mining industry both for employment and as a source of income.

Table 3 *Percentage distribution of employed* according to main occupation*

Occupation	Ratnapura			Kalutara			Kegalle		
	Male	Female	Total	Male	Female	Total	Male	Female	Total
Agricultural operator	45·3	6·3	51·6	48·7	1·8	50·5	36·5	5·1	41·6
Crafts	1·4	—	1·4	1·7	0·2	1·9	2·6	—	2·6
Trader	5·3	0·2	5·5	5·0	—	5·0	8·8	—	8·8
Gemming activities	11·6	—	11·6	—	—	—	—	—	—
Ayurvedic Physician	0·6	0·2	0·8	0·8	—	0·8	0·9	0·2	1·1
Agricultural Labourer	3·5	2·2	5·7	4·0	1·0	5·0	2·6	1·1	3·7
Non-Agricultural Labourer	4·1	3·0	7·1	5·0	0·2	5·2	12·1	1·9	14·0
White collar jobs	10·4	5·9	16·3	23·4	8·2	31·6	17·0	11·2	28·2
Total	82·2	17·8	100·0	88·6	11·4	100·0	80·5	19·5	100·0

*Excluding employed children

(*Source* : Jayasena, W. G. and Herath, H. M. G. (1984)

Distribution and use of land

Land forms the most basic resource in rubber production. The use of land is influenced by its size, ownership and distribution, which are examined below for the rubber smallholders, The number of holdings and the percentage of total land area by holding-size are given in Table 4 for all three districts.

Table 4. *Distribution pattern of rubber smallholdings and extent of land by holding size*

Holding size (acres)	Ratnapura		Kalutara		Kegalle	
	No. of holdings	% of total extent	No. of holdings	% of total extent	No. of holdings	% of total extent
Below 1	36	1·9	43	3·5	39	2·0
1 to below 2	86	8·7	101	17·0	91	10·7
2 to below 4	92	19·7	104	35·7	79	19·0
4 to below 10	61	30·2	46	34·0	71	39·4
10 to below 25	19	23·1	6	9·8	18	22·6
25 to below 50	6	16·1	—	—	2	6·3
TOTAL	300	100·0	300	100·0	300	100·0

Source : Jayasena, W. G. and Herath, H. M. G. (1984)

It is seen that most holdings are concentrated in the different size groups below 10 acres in all three districts. The 1—2, 2—4 and 4—10 acre size groups are the most predominant for Ratnapura, Kalutara and Kegalle Districts, comprising approximately 80 percent of the holdings. However, in terms of area the 2—4 and 4—10 acre size groups are predominant in all three districts.

The distribution of the holdings and the extent of land under each category attests to some degree of inequality in land distribution. For example, 91·7 percent of holdings in the Ratnapura District is below 10 acres but this group accounted for only 60·9 percent of total extent of land. In Kalutara and Kegalle, 98·0 and 93·3 percent of the holdings are below 10 acres accounting for 90·2 and 71·1 percent of total land area, respectively.

Structure of land ownership

The pattern of ownership of rubber land indicates that there are five broad categories. Sole ownership is the predominant ownership category in all districts. Sole ownership was observed in 74·9, 78·3 and 90·0 percent of land in the Ratnapura, Kalutara and Kegalle Districts, respectively. The joint owner and operator group comprised 14·2, 5·2 and 4·2 percent of the land the Ratnapura, Kalutara, and Kegalle Districts, respectively.

It was also observed that the substantial extent of rubber lands amounting to 5·8 percent to 10·9 percent are still under various tenure systems such as Viharagam, Devalagam, Nindagam, LDO and encroachments where operators cannot provide any clear titles. The impact of these joint and uncertain ownership on production has been amply demonstrated in other contexts. There is lack of incentive and initiative amongst the farmers to invest in production where clear titles are absent. This is particularly important in perennial crop production such as rubber which is a form of long term investment. The disincentive effects of uncertain tenure on rubber smallholdings should thus be carefully borne in mind.

Type of crops grown

Another important feature observed is that most smallholder rubber farmers surveyed cultivated other crops such as paddy, coconuts and mixed crops. The average size of the rubber holding and that of other crops in the three districts is given in Table 5.

Table 5. *Average size of holdings allocated to different crops (acres)*

Crop	Ratnapura	Kalutara	Kegalle
Rubber	4·0	2·5	3·6
Tea	1·1	—	1·6
Coconut	1·3	1·2	2·1
Paddy	1·5	1·5	1·2
Mixed crops	1·9	1·0	1·3

Source : Jayasena, W. G. and Herath, H. M. G. (1984)

The average size of rubber holding is 4 acres in the Ratnapura District, and 3·6 in the Kegalle District. In Kalutara it is 2·5 acres. The farm sizes of most other crops do not change when the size of the rubber holding increases. The average extent of land allocated to other crops is larger than the average rubber holding for farmers having less than one acre of rubber in all three districts. The paddy acreage varies from 1·1 to 2·3 acres in Ratnapura. In Kalutara and Kegalle it varies from 0·8 — 3·3 acres and 0·6—3·0 acres, respectively. Tea did not account for any significant acreage in the Ratnapura and Kegalle Districts and was totally absent in the Kalutara District. The proportion of other crops to rubber declines very rapidly with increase in the rubber holding size.

Pattern of labour use

Labour is also an indispensable input in rubber production. Tapping is the most labour intensive operation and an examination of labour use in tapping gives an insight into the labour use pattern amongst the smallholders. For this reason labour use for tapping is examined in Table 6.

Table 6. *Percent farmers reporting different types of labour for rubber tapping*

Type of labour	Ratnapura	Kalutara	Kegalle
Family labour	65·9	68·8	42·1
Hired labour	17·5	28·9	56·5
Family and hired labour	3·1	2·3	1·4
Share basis	13·5	—	—

Source : Jayasena, W. G. and Herath, H. M. G. (1984)

It is obvious that family labour forms the predominant source of labour. Approximately 65·9, 68·8 and 42·1 percent of farmers used family labour in the Ratnapura, Kalutara and Kegalle Districts, respectively. In Kegalle hired labour appears more important than family labour. Share labour although not present in the Kalutara and Kegalle Districts constituted 13·5 percent in the Ratnapura District. The number of farmers using hired labour over those using family labour increases when the holding size increased. In contrast most estates have a resident labour force under a centralised form of management.

Income profile of rubber smallholders

The type of activity and crop combinations determine the level and distribution of income. The average monthly household income derived from all sources, in the Ratnapura, Kalutara and Kegalle Districts are Rs. 1,562, Rs. 1,389 and Rs. 2,303 respectively. The average incomes increase with increase in the size of holding. The below one acre size group in the Ratnapura, Kalutara and Kegalle districts had an average household income of Rs. 1,021, Rs. 796 and 1,053, respectively.

It is necessary to point out that rubber is not the only source of income for most farmers. Most rubber farmers grow other crops such as paddy, coconuts, mixed crops etc., while some family members engage in other forms of employment. Thus most farmers obtain incomes from agricultural and non-agricultural sources, other than rubber. The percentage composition of income per household by source and holding size is given in Table 7. The overall average non-agricultural income accounts for 56·7, 48·7 and 31·0 percent for the Ratnapura, Kalutara and Kegalle Districts, respectively. On an average basis income from rubber comes first in the Kegalle District while it comes second both in the Ratnapura and Kalutara Districts.

Implications for development

The foregoing discussion highlights the most salient socio-economic characteristics of rubber smallholders in Sri Lanka which have important implications for their development. The basic approach for development of the rubber smallholder sector lies in the development of high yielding technologies which overcome the land constraint. Usually high yielding clones are associated with other improved management practices such as fertilizer use and pest and disease control. In addition to new technologies other institutional and infrastructural facilities must be made available to facilitate the diffusion and adoption of such technologies. It is important although not realized too often that the technologies developed should be consistent with the resource endowment of the smallholders (Ruttan and Binswanger, 1978). It was already pointed out that smallholders lack capital but have an abundance of labour. Thus technologies developed for them should be more labour intensive but less capital intensive.

The low level of incomes of small farmers make them reticent to adopt new innovations. This is particularly significant in the case of perennial crops such as rubber where funds once committed cannot be easily reversed. Also particularly in the case of perennials like rubber where the asset provides some income although due for replacement the farmers show reluctance to replace their assets since they do not wish to forego their present incomes, however, little it may be. The examination of the age distribution of smallholder rubber confirmed this observation. In the Ratnapura District for example 18·3 percent of the smallholder rubber area was above 30 years old, although the percentages are lower in the other two districts. Although subsidies are provided to cover costs in replanting the deferment of income during the immature phase has discouraged many farmers from undertaking replanting. Intercropping has now been encouraged during the immature phase in order to recoup some of the incomes foregone. Even this has not had its desired effect and a subsidy for intercropping itself may have a salutary effect on smallholder replanting. Even ownership problems which are more prevalent amongst the smallholders act as a disincentive in adopting new technologies as observed earlier.

Where replanting is effected it is again observed that most smallholders have done so with the old clones available rather than the new ones. This is evident in Table 8 where the proportion of RRIC varieties developed by the Rubber Research Institute of Sri Lanka (RRISL) is very low. However, these RRIC clones especially 100 series more diseases resistant and more vigorous compared to PB 86, an older clone introduced into Sri Lanka in the 1940s.

Table 7. *Percentage composition of household income by sources and rubber holding size*

Holding Size (acres)	Ratnapura				Kalutara				Kegalle			
	Rubber	Paddy	Other* agricultural incomes	Non-agriculture**	Rubber	Paddy	Other* agricultural incomes	Non-agriculture**	Rubber	Paddy	Other* agricultural incomes	Non-agriculture**
Below 1	13·1	13·6	4·6	68·7	21·9	10·0	11·1	57·0	20·9	14·7	22·9	41·5
1 to below 2	14·8	9·4	3·4	72·4	25·9	13·3	9·8	51·0	22·3	12·5	18·7	46·5
2 to below 4	28·9	9·6	5·1	56·4	31·9	15·6	7·6	44·9	30·7	14·4	20·5	34·4
4 to below 10	29·8	12·2	5·9	56·1	32·9	9·5	5·5	52·1	42·5	14·9	16·2	26·4
10 to below 25	58·2	5·9	3·7	32·2	46·7	13·8	3·7	35·8	66·7	9·6	8·2	15·5
25 to below 50	68·0	8·4	2·6	21·0	—	—	—	—	90·8	9·1	—	—
Overall district :	28·4	10·2	4·7	56·7	30·8	12·8	7·7	48·7	39·2	13·3	16·5	31·0

* Coconut, tea, arecanut, cinnamon, cloves and livestock
** White collar and other regular jobs, gem mining and off farm incomes

Source : Jayasena, W. G. and Herath, H. M. G. (1984)

Table 8. *Percentage area of smallholdings under different rubber clones*

Clone	Ratnapura	Kalutara	Kegalle
PB 86	60·6	58·8	66·0
RRIC 45	2·4	3·0	11·5
RRIC 52	—	0·9	1·3
RRIC 37	—	—	1·1
RRIC 100	1·1	—	—
RRIC 101	—	—	—
RRIC 102	—	—	—
RRIC 103	—	—	—
Wagga 6278	0·4	—	—
Unidentified Budded	6·2	8·1	6·3
Clonal rubber	19·3	20·9	8·4
Seedling Rubber	10·0	8·3	5·4

Source : Jayasena, W. G., Herath, H. M. G. (1984 b)

Several reasons may be adduced for this behaviour. It was noted that less than 4 percent of the farmers are aware of the RRIC varieties (Jayasena and Herath, 1984 b). The farmers are risk averse due to low income and hence do not venture into accepting innovations that are untried. The importance of extension agents to create awareness and convince them is thus an imperative. The high level of literacy and education of smallholders may be a positive sign in this connection. It is also useful to have demonstration plots which will have a visual impact on them and they are more likely to adopt new innovations.

Even in the adoption of management practices the specific characteristics of smallholders result in certain patterns of adoption. For example, fertilizer use which is one important management practice but capital intensive, is still unsatisfactory. A survey in 1981 indicated that only 27·7 and 19·3 percent of the immature rubber extent and 4·6 and 5·1 percent of the mature rubber extent farmers in the Ratnapura, and Kalutara Districts had been fertilized (Jayasena and Herath 1984). However, in 1983, in a repetition of the same survey revealed that more than 90 percent of the farmers applied fertilizer for immature rubber. However, the frequency of application is not adequate. Application of fertilizer for mature rubber also very poor being 3·6, 6·2 and 15·4 percent of the extent in the Ratnapura, Kalutara and Kegalle Districts, respectively. (Jayasena and Herath 1984 b). This was found to be due to lack of awareness of the correct time and amount, inadequate incomes, non availability of fertilizer at required time and lack of interest. It was also noted that practices which require only labour such as weed control, cover cropping etc., appear to be more readily adopted by a wider spectrum of farmers. The implication of this is that when management practices are developed, it is useful to concentrate on new innovations that use more labour than capital. Thus research on chemical weed control or yield stimulants which are capital intensive appear a questionable approach to development of the smallholder rubber sector, (Barlow and Peries, 1977).

The particular social circumstances of farmers have pre-disposed them to certain patterns of exploitation of rubber. For example, although half spiral alternate daily is the recommended system of tapping many smallholders adopt the half-spiral daily system due to their necessity to have daily incomes (Table 9). Amongst the estates usually the alternate daily system is followed. This more intensive tapping systems can lead to advancement of senescent and also a higher incidence of disease particularly panel diseases. There is a need to educate the farmers on the need to tap less intensively. More importantly it is necessary to take account of the need of daily incomes for small farmers and develop varieties that would withstand more intensive tapping. At present, in most yield trials alternate daily system of tapping is used as a standard method in screening new clones which should be changed to more intensive tapping systems as well particularly for small holders.

Table 9. *Percent of farmers adopting different tapping systems (for all three districts)*

Holding size (acres)	Half spiral daily %	Half spiral alternate daily %	Half spiral third daily %	2-half spiral daily %	2-half spiral alternate daily %	Slaughter tapping %	Mixed tapping systems %
Below 1	35·7	—	—	21·4	7·1	—	42·8
1 to below 2	36·5	13·5	1·4	14·9	6·8	18·9	24·3
2 to below 4	35·9	17·4	2·2	18·5	1·1	23·9	18·5
4 to below 10	50·0	11·3	—	29·0	4·8	21·0	14·5
10 to below 25	46·2	46·2	—	38·5	7·7	7·7	30·8
25 to below 50	—	66·7	—	—	—	—	66·7
Total	39·5	15·9	1·2	20·9	4·3	19·4	21·3

Source : Jayasena, W. G. and Herath, H. M. G. (1984b)

The low level of producer incomes, lack of proper processing utencils and also lead to poor knowhow, unsatisfactory marketing system also lead to poor processing standards by smallholders. It was noted that farmers in most of the small sized holdings do not produce any RSS1 which is the best grade. Most of them produce RSS2 or RSS3 (Jayasena and Herath, 1984). The low quality produce leads to low incomes which thus creates a vicious circle tending to perpetuate the present system. The small farmer is in a state of low income equilibrium. There is a need to improve infrastructure so that the necessary facilities are available to produce high grade rubber.

The growing of several crops imply that their labour and capital resources are directed towards several crops. This tendency could be strongly felt amongst the smallest farmers. They have limited resources such as labour and capital to be used for all crops. Diversion of these resources to other crops during critical periods could affect the operations of the rubber stand. Management operations and even tapping could be sacrificed for urgently needed cultural operations in other crops such as paddy. Several potential problems could arise from this scenario. The effectiveness of measures such as subsidies credit facilities could be jeopardised due to possible diversion of such facilities to other crops. Fungibility of agricultural credit has been observed to be a particular problem amongst peasant farmers in developing countries. Thus, unless measures to counteract such tendencies are effectively enforced, underutilisation of resources for the target crop could occur. Also, when several crops are grown the need and the ability to specialize in any one crop which facilitates sharpening of technical skill are neither needed nor present. This could thwart introduction of new technology. Further, when the farmer has a crop portfolio it affords considerable flexibility for him under conditions of price variability. Thus, changes in the price of rubber can result in wide fluctuations in supply. The price elasticity of supply amongst the smallholders could be generally higher than what is expected for perennial crops. The resulting uneven supply can have serious repercussions on productions and exports. If these fluctuations are significant, it may have implications for price policy. From the farmers point of view however, it is a risk averse strategy and farmers may show preference for such a system due to their low tolerance to risk.

CONCLUSION

The small sample of rubber smallholders investigated in this study limits the generalization of the research findings to the wide spectrum of producers. Undoubtedly, a large sample of farmers, is necessary to arrive at more firm conclusions. Generalizing from the findings of this study, however, leads to an important statement about development of rubber smallholders. One of the major conclusions is that the type of technology developed should be consistent with the factor endowment of smallholders. They should particularly be labour intensive but less capital intensive. Some of the factors investigated such as low income, uncertain tenure, mixed cropping, small farm size all help explain why rubber smallholders are slow to change their production patterns while the estates are far superior in this respect. Even institutional patterns should be geared to the particular socio-economic features of the smallholders. If the above factors are considered in development policy, it will impinge in a substantial way on the well being of large number of rubber farmers and will have a crucial impact on the success or failure of important aspects of development planning.

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PATHOGENICITY VARIABILITY OF *RIGIDOPORUS LIGNOSUS* AND *PHELLINUS NOXIUS*

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INTRODUCTION

Researches devoted to the biology of root and butt rot fungi have shown a variability at the physiological and pathogenic levels within the populations of these microorganisms (Huttermann *et al.*, 1979 ; Morrison, 1982 *inter alia*). In tropical climates, the white rots of *Hevea brasiliensis* (Wild, ex. Adr. de Juss) Mull. Arg. caused by *Rigidoporus lignosus* (Kl.) Imazeki and *Phellinus noxius* (Corner) G. H. Cunn, have been comparably studied (John, 1966 ; Lim, 1970 ; Peries and Irugalbandara, 1973 ; Liyanage and Peries, 1973 ; Geiger *et al.*, 1976 ; Fox 1977 ; Nicole *et al.*, 1982a, b ; Tran Van Canh, 1982 ; Nandris *et al.*, 1984).

In the context of the ORSTOM research program on these parasites in the Ivory Coast, epidemiological surveys in rubber plantations have shown the existence of differences in the course of the infectious cycle, both among different foci and among trees in the same focus (Nandris *et al.*, 1983a). These differences can be attributed to either differences in host reaction capacities (Geiger *et al.* 1983) or to variations in pathogenicity of the infecting strains. In order to decide between these two hypotheses, a pathogeny study was carried out in a greenhouse by artificially infecting young rubber trees with different isolates of each of the above parasites. In parallel, the possibility of a physiological heterogeneity in these strains was sought *in vitro* (manuscript in preparation).

The results obtained showed pathogenic variations in the *R. lignosus* and *P. noxius* strains collected from various hosts in West Africa. The present review initially describes prior results acquired in this field and then expands on a pathogenicity analysis of a population of isolates from the same rubber plantation. Finally, an attempt is made to correlate the parasitic behaviour of these strains with saprophytic characteristics observed *in vitro.*

MATERIALS AND METHODS

Artificial Infections

Fungal strains

The *R. lignosus* and *P. noxius* strains were isolated from the roots of trees parasitized by the two fungi. The nature of the host plantation or forest varieties and the geographic origins are given in Table 1. Strains were grown on 2% malt medium (Difco) containing 2% agar, at 28°C in the dark. The stock cultures of isolates were kept in malt medium in test tubes at 16°C.

Table 1. *Characteristics of the various tested isolates*

Rigidoporus lignosus isolates collected in different areas from various hosts.

Isolate (Stock n°)	Country origin	Host	Isolation date
1*	South East Ivory Coast	*Hevea brasiliensis*	1978
9	East Ivory Coast	Primary forest tree	1978
13*	West Ivory Coast	Primary forest tree	1978
21*	South East Liberia	*Hevea brasiliensis*	1979
37*	South East Ivory Coast	*Hevea brasiliensis*	1981
38*	Cameroon	*Hevea brasiliensis*	1981
42	South West Ivory Coast	*Hevea brasiliensis*	1981
52*	East Ivory Coast	*Tectona grandis*	1981

Rigidoporus lignosus isolates collected in the same rubber plantation

Isolate (Stock n°)	Country origin	Host	Isolation date
9		*Hevea brasiliensis*	1978
36		,,	1981
64A	East Ivory Coast	,,	1982
64C		,,	1982
64D		,,	1982
64E		,,	1982
64F		,,	1982

Phellinus noxius isolated in different areas from various hosts.

Isolate (Stock n°)	Country origin	Host	Isolation date
7	West Ivory Coast	Primary forest tree	1978
45	East Ivory Coast	*Cedrela odorata*	1981
31	South West Ivory Coast	*Hevea brasiliensis*	1980
35	East Ivory Coast	*Hevea brasiliensis*	1981
39	Cameroon	*Hevea brasiliensis*	1981
2	South West Ivory Coast	*Hevea brasiliensis*	1977
32	South West Ivory Coast	*Cedrela odorata*	1980

* Isolates used as reference in pathogenicity test of *R. lignosus* isolates collected in the same rubber plantation.

The inoculum

Fragments of rubber tree branches (8 cm long by 1·5 cm in diameter) were deposited in 1 liter Roux bottles containing 100 ml of water. Each bottle was then autoclaved for 1 h at 100°C and then inoculated with 8 mycelian implants (5 mm in diameter) removed from the periphery of a 5 day-old preculture on malt agar. These infected sticks were used as inoculum 11 months after their inoculation with *R. lignosus* and 5 months after that by *P. noxius.*

The experimental system of infecting rubber trees

Artificial infections were performed in greenhouse under controlled conditions as described by Nandris *et al.*, (1983b). Young plants (clone GT 1) obtained from seeds were transferred to a vegetation tub (1 m^3) filled with forest soil. At the age of one month the plants were infected with five inoculum sticks deposited at a depth of 20 cm in the soil against the tap root. The moisture content of the soil (on a volume basis) was maintained at 21% for *R. lignosus* and at 19% for *P. noxius,* by controlled watering determined by a neutron moisture gauge. Thirty rubber plants in the same container were infected with each isolate. Non-infected plants, as well as those whose tap roots were surrounded with sterile stems, were used as controls. The experiment lasted about 5 months, from October to March.

Two series of experiments were performed using this general outline :

— one utilized strains isolated from various hosts and from diverse geographic origins. During the experiment, 10 randomly chosen plants were removed and examined 2 months after infestation by each of the isolates of the two parasites ;

— the other series was carried out in order to determine the possible variability of isolates collected in the same plantation. " Reference " strains, whose previously tested aggressiveness was known, were used in parallel to these strains.

In this context, it is to be noted that aggressiveness levels of these strains, measured yearly for 2 years, varied only slightly (Table 2).

Table 2. *Severity indexes of some isolates of* R. lignosus *recorded during 2 successive experimentations*

Isolates	1983		1984	
(Stock n°)	Severity Index	Standard Error	Severity Index	Standard Error
1	8,4	0,56	8,4	0,46
21	8,1	0,76	8,23	0,55
37	5,4	1,16	5,4	1,00
38	8,3	0,62	8,3	0,39
52	8,9	0,22	8,6	0,41

Evaluation of the pathogenicity

The quantitative determination of the infestation level of each plant was evaluated on the basis of the scoring scale shown in Table 3. The mean of the severity index (S. I.) attributed to each of the 30 plants in the same container, is a reflection of the aggressiveness of the isolate tested. In addition to the presence of hyphae on and in the tap root, as well as the proportion of necrotic tissue, the following criteria were systematically taken into account :

Table 3. *Stages in the development of the disease*

Severity scale of the attack	Visual rating
	RIGIDOPORUS LIGNOSUS
0	no mycelium on roots
1	non-aggregate hyphae
2	rhizomorphs
3	rhizomorphs and punctual penetration
4	rhizomorphs and localized necrosis
5	rhizomorphs and partial tap root decay $< 20\%$
6	rhizomorphs and 20 to 50 % tap root decay
7	rhizomorphs and tap root decay $> 50\%$
8	foliar symptoms
9	plant death
	PHELLINUS NOXIUS
0	no mycelium on roots
1	mycelial crust in formation
2	well-formed mycelial crust
3	mycelial crust and punctual penetration
4	mycelial crust and localized necrosis
5	mycelial crust and partial tap root decay $< 20\%$
6	mycelial crust and 20 to 50 % tap root decay
7	mycelial crust and tap root decay $> 50\%$
8	foliar symptoms
9	plant death.

- growth of stem (measured weekly),
- the percentage of contaminated or penetrated or presenting foliar symptoms or dead plants,
- the percentage of plants manifesting anatomic reactions (secondary rhizogenesis) which have been described elsewhere (Nicole *et al.*, 1983),

- the localization of necrosis into the tap root,
- the period of time between the appearance of foliar symptoms and death,
- the date of plant death,
- enzymatie activities (laccases, hydrolases) of the fungus in the inoculum, assayed before, during and after the experiment as described by Geiger (1975).

In vitro physiological variability of isolates

Effect of pH and temperature on the growth rate

The effect of pH on fungal growth rate was determined by growing the different strains at 30°C on malt medium where the pH was adjusted with 1 N HC 1. or NaOH, between values of 3 and 9.

The effect of temperature on fungal growth was determined by depositing cultures on malt agar and growing them in incubators maintained at 20, 25, 30 and 35°C.

In both cases, differences among strains were evaluated on the basis of their growth after 3 days of culture (mean of two perpendicular thallus diameters).

Evaluation of wood degrading capacity

Test blocks were formed from pieces of rubber tree wood ($5 \times 1 \times 0{\cdot}3$ cm in size) taken from healthy tap roots in plantations. After drying, the test blocks were placed in constriction tubes containing 20 ml of water. Each tube was inoculated with a mycelian implant. After 7 months of incubation, the infested blocks were used for two series of tests. Wood degradation, *i.e.* the loss in dry weight (DWL) and lignin content (LIG) were measured. In addition, fungal enzymatic activities in the wood were measured : beta-glucosidase (β-glu), alpha-galactosidase (α - gal), beta-galactosidase (β - gal), pectinase (pect), cellulase (cell.) and catalase (cat.). Conventional techniques were used for these assays (Geiger, 1975).

Statistical interpretation of the results

All the data of each experiment were subjected to two types of processing. A multidimensional principal component analysis (PCA) was used to establish correlations existing among variables and to furnish a schematic representation of the data recorded, enabling individuals to be compared among themselves. Multiple regression with regressive selection of variables was used to correlate a given variable of one strain with a set of variables, *e.g.* the S. I. of a strain established *in vivo* with its enzymatic characteristics. The validity of the resulting correlation coefficient was determined with the F test at the 5% confidence level.

RESULTS

Pathogenicity of isolates of *Rigidoporus lignosus*

The study of the pathogenicity of strains collected from forest varieties in various regions of West Africa has shown the existence of significant difference in their infectious behaviour towards rubber plants (Nandris *et al.*, 1984). This variability is expressed as early as the second month after infestation and was particularly pronounced after the 5 months of the experiment (Table 4).

Even though the totality of plants infected with each isolate was contaminated and penetrated — in the absence of qualitative differences among strains — the percentages of plant mortality in fact varied between 10 and 95%, depending on the isolate. In addition, differences in infestations were also manifested by the various indicators characterizing parasitic attack (Table 4).

Statistical processing of the data showed that the first two axes of the PCA accounted for 97% total variation. Fig. 1a, b thus gives a satisfactory representation of the structure of the parasite population and enables the isolates to be mutually discriminated.

In order to further define this analysis, additional experimentation was carried to test the pathogenic capacity of *R. lignosus* strains isolated in the same rubber plantation and mutually separated by a distance of several hundred meters. The data gathered for each isolate (Table 5) show, as before, that there is a considerable variability among the seven isolates examined. This variability is most apparent at the level of the percentage of necrotic tissue and of the number of dead plants. It was also noted that some strains preferentially attacked the lower part of the root system and then progressively worked upwards towards the collar, while others simultaneously attacked the collar and the tap root.

Differences in aggressiveness among these strains were confirmed by the mortality rates (Fig. 2a, b). Thus, attack by the most pathogenic strains was brutal, with mortality occurring as soon as the sixth week. In the case of other isolates (N° 64 D, 9 and 64 A), on the other hand, the infestation remained quite moderate. The statistical positioning of the isolates on the basis of their characteristics is shown in Fig. 3a, b. For the sake of comparison, reference strains are also included in this representation (axes 1 and 2) but they were not considered directly in the analysis of the seven strains examined. It should be noted that the classification obtained for some strains on the basis of plant mortality level (Table 5) differs from that furnished by the PCA for all the variables considered.

In vitro physiological variability of *R. lignosus*

In parallel to the demonstration of *in vivo* pathogenic variability, we carried out a study of the growth and physiological characters of these strains. It was found first that the isolates could not be descriminated on the basis of growth rates on agar medium as a function of pH and of temperature. The analyses of test blocks degradation parameters (loss of weight and lignin contents) and of enzymatic characteristics, showed consequent variations of data recorded for the isolates of each parasite. Nevertheless the existence of a correlation between enzyme activities and loss of weight was established.

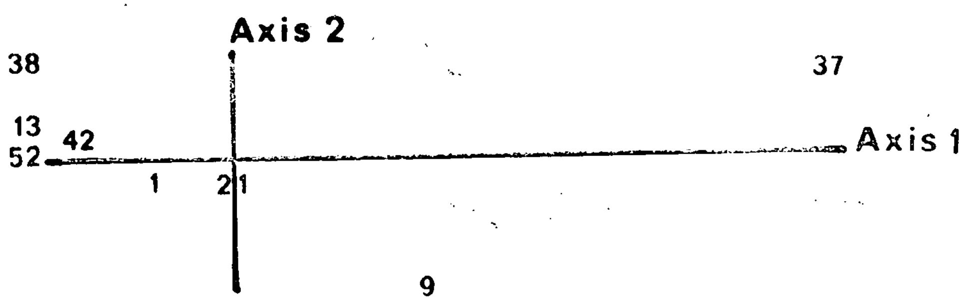

Fig. 1. Pathogenicity variation among *Rigidoporus lignosus* isolates collected in various areas from various hosts:

Fig. 1a. position of the strains on the plan 1 — 2 of the principal component analysis (PCA). The most pathogenic strains lie on axis 1 negative.

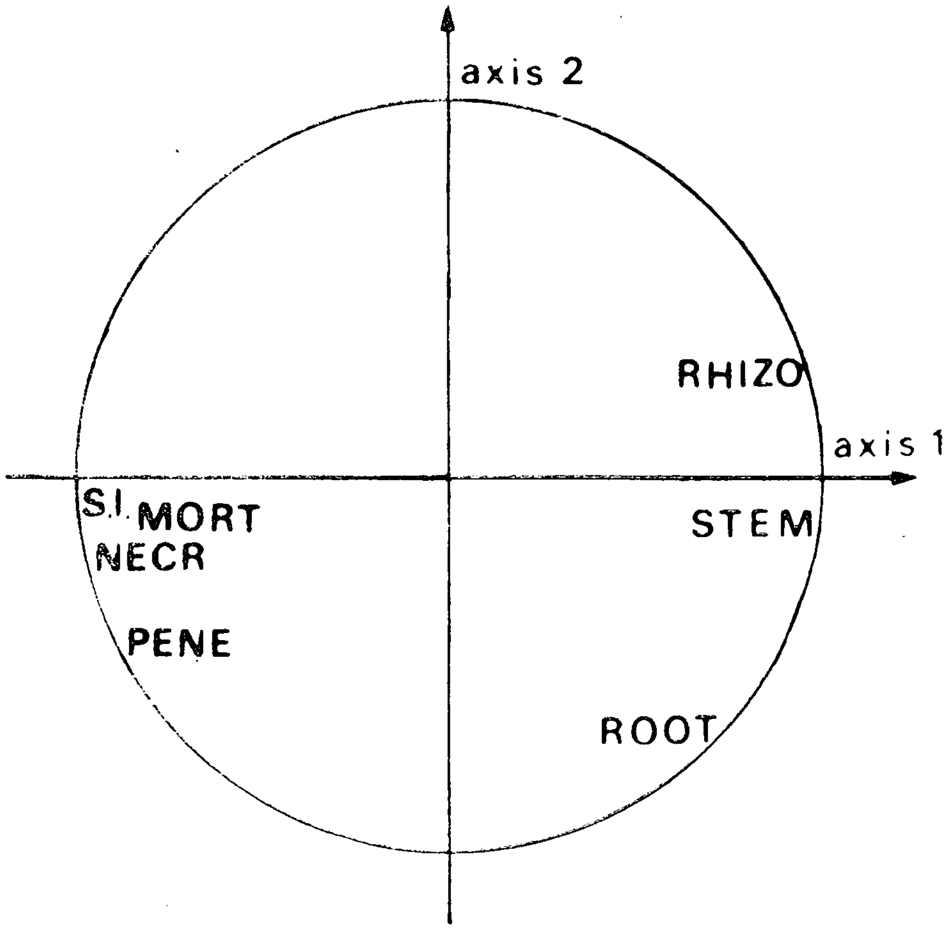

Fig. 1b. Position of the variables on the correlation circle.

MORT : mortality ; NECR : root necrosis ; PENE : root penetration ; RHIZO : reactional rhizogenesis ; ROOT : length of root ; SI : severity index ; STEM : length of stem ; variables MORT and SI have nearly the same coordinates.

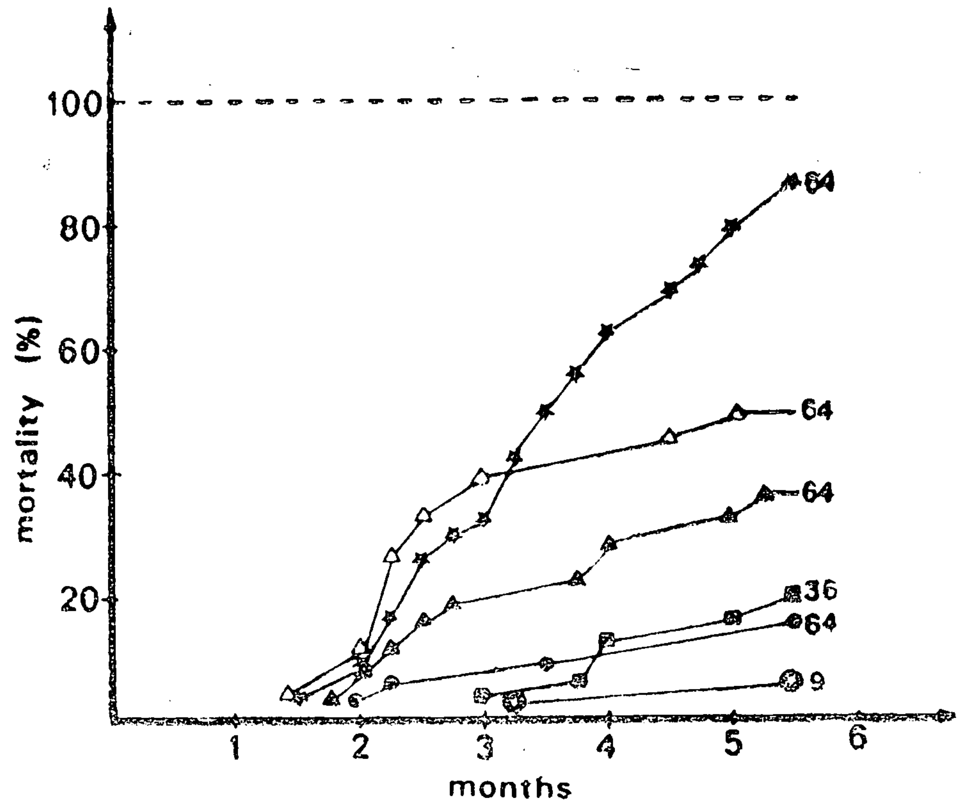

Fig. 2. Rates of mortality of plants inoculated with isolates of *Rigidoporus lignosus*, collected in the same plantation.

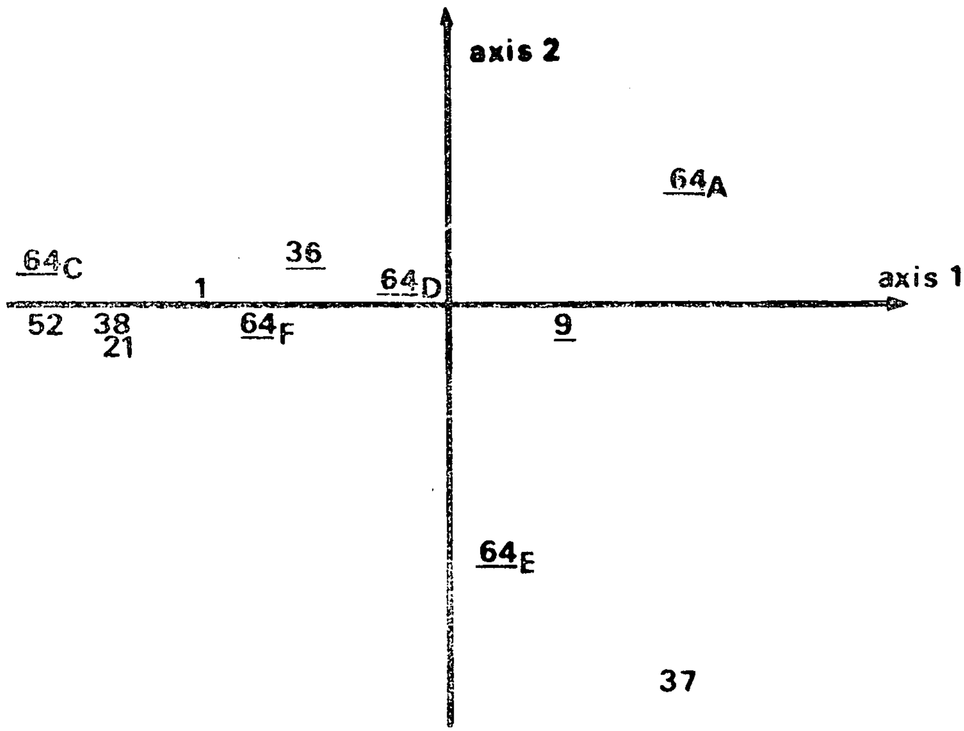

Fig. 3. Pathogenicity variation among *Rigidoporus lignosus* isolates collected in the same rubber estate :

Fig. 3a. position of the strains on the plan 1 — 2 of the PCA. The most aggressive strains lie on axis 1 negative.

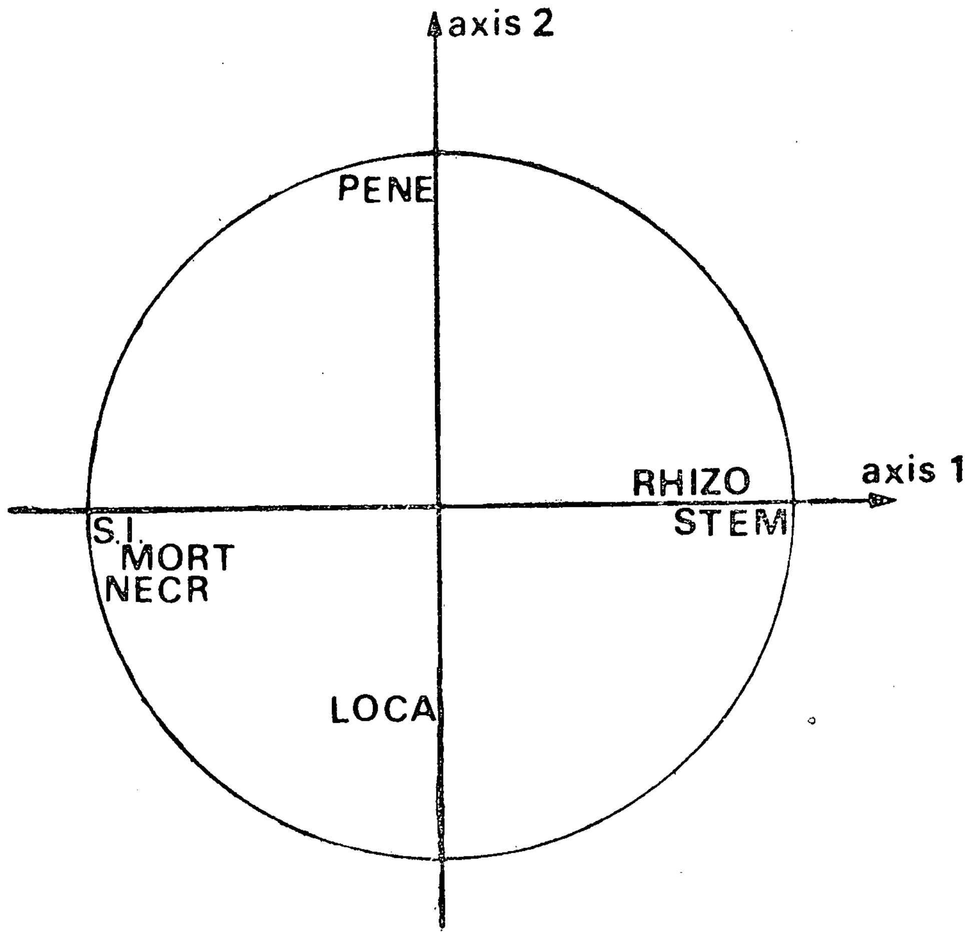

Fig. 3 b. **Position of the variables on the correlation circle.**

LOCA : location of the infection site ; MORT : mortality ; NECR : root necrosis; PENE : root penetration ; RHIZO : reactional rhizogenesis ; SI : severity index ; STEM : length of stem.

Table 4. *Incidence and severity on rubber seedlings of* Rigidoporus lignosus *isolates collected in different areas from various host*

RATING CRITERIA

Isolates (Stock n°)	Severity Index	Standard error	Growth of stem cm	Contamination %	Penetration %	Foliar symptoms %	Mortality %	Secondary rhizogenesis %	Amount of decay %	Location of infection site
52	8,9	0,22	41	100	100	0	95	0	91	Tap root
42b	8,7	0,5	47	100	100	0	90	5	78	Tap root + collar
13	8,7	0,37	44	100	100	0	85	5	86	Tap root
1	8,4	0,56	47	100	100	0	75	10	72	Tap root + collar
38	8,3	0,62	48	100	100	5	70	0	85	Tap root
21	8,1	0,76	54	100	100	0	70	15	60	Tap root + collar
9	7,15	1,08	55	100	100	5	45	10	45	Tap root + collar
37b	5,47	1,16	78	100	90	0	10	60	32	Tap root

means of 20 inoculated plants

Table 5. *Incidence and severity on rubber seedlings of* Rigidoporus lignosus *isolates, collected in the same rubber plantation*

Isolates (Stock n°)	RATING CRITERIA									
	Severity Index	Standard error	Length of stem cm	Contamination %	Penetration %	Foliar symptoms %	Mortality %	Secondary rhizogenesis %	Amount of decay %	Location of infection site
64C	8,8	0,23	59	100	100	6,6	86,6	13	73	Tap root + collar
64F	7,9	0,50	71	100	100	3,3	50	35	68	Tap root + collar
36	7,3	0,42	72	100	100	0	20	23	59	Tap root
64E	7	0,93	84	100	93	0	36,6	32	55	Tap root + collar
64D	6,8	0,48	83	100	100	0	16,6	30	45	Tap root
9	5,7	0,67	102	100	100	0	6,6	17	27	Tap root
64A	5,3	0,54	97	100	100	0	6	43	17	Tap root

means of 30 inoculated plants.

Attempt to correlate pathogenicity and physiological characteristics of *R. lignosus* strains

Table 6 contains the values characterizing the most representative variables (*a priori*) of the saprophytic behaviour of the isolates, and also the SI of the attacks. The multiple regression test enabled us to demonstrate the absence of significant correlations between pathogenicity and enzymatic activities assayed *in vitro* (Table 7).

As a result of the lack of correlation between these two types of variation, it was of interest to determine the effect of the *in vitro* characteristics on the structure of the parasite population, previously determined on the basis of only pathogenic criteria (see Fig. 1).

Four active non-correlated variables were used for this new PCA : the SI, the percentage of plants reacting to the attack, the weight loss of the test blocks, and the growth rate of the isolates in culture at 30°C and optimal pH. This analysis generated a new structuration of the population (Fig. 4a) in which close to 88% (55 + 33) of the recorded variation can be accounted for by axes 1 and 2. The comparison of positions of individuals and of variables (Figs. 4a, 4b) stresses the preponderant role of the SI on the configuration of the population. Although the statistical representation of this set of isolates remains globally comparable to that seen in Fig. 1, it is nonetheless noted that there is a better discrimination among the five most aggressive isolates.

Pathogenic and physiological variabilities of *P. noxius* isolates

Experimentation identical to that carried out with *R. lignosus* was performed with *P. noxius* isolates. Table 8 represents the data obtained *in vitro* and *in vivo*, respectively ; Fig. 5 shows the structure of fungal population. Although there are obvious quantitative differences in the parasitic and saprophytic behaviour of the two fungal species, the conclusions of the analysis performed with the *P. noxius* strains are qualitatively similar to those obtained with *R. lignosus.*

DISCUSSION

The analysis of the results shows that variations exist in the pathogenic behaviour of *R. lignosus* and *P. noxius* isolates collected from different hosts and from different regions in West Africa This variability must be considered when practical means for combatting these root diseases are put into practice. Henceforth, resistant tree selection and fungicide screening will no longer involve a single strain for performing tests for extrapolating the results to all the strains comprising the parasite population of a given region.

A comparable analysis has been carried out by Liyanage *et al.* (1977) with *R. lignosus* isolates collected in different Sri Lanka rubber plantations. Even though the general experimental design and the main conclusions are analogous in both studies, there are nevertheless certain differences.

First, the authors stated that the most aggressive strain differed from the others tested in this geographic region by the lack of rhizomorph differenciation, regardless of medium conditions. The authors also stated that the rhizomorph was initiated only

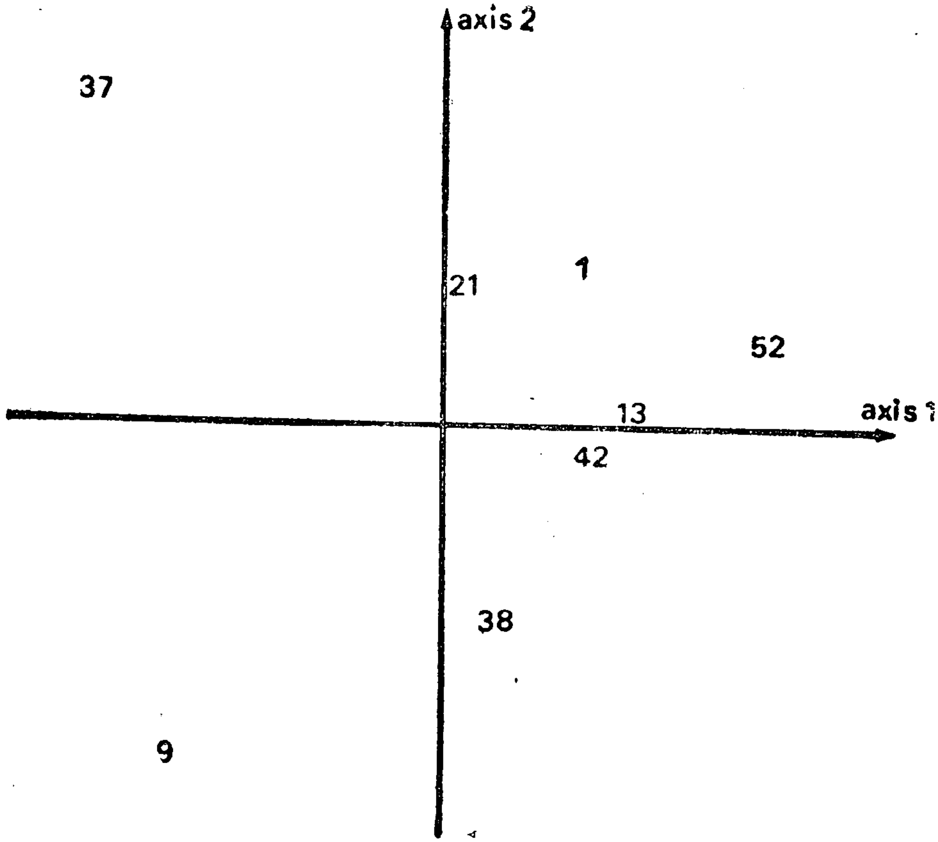

Fig. 4. **Correlation between *in vitro* and *in vivo* characteristics of *Rigidoporus lignosus* isolates.**

Fig. 4a. **position of the. strains on the plan 1 — 2 of the PCA. The most aggressive strains lie on axis 1 positive.**

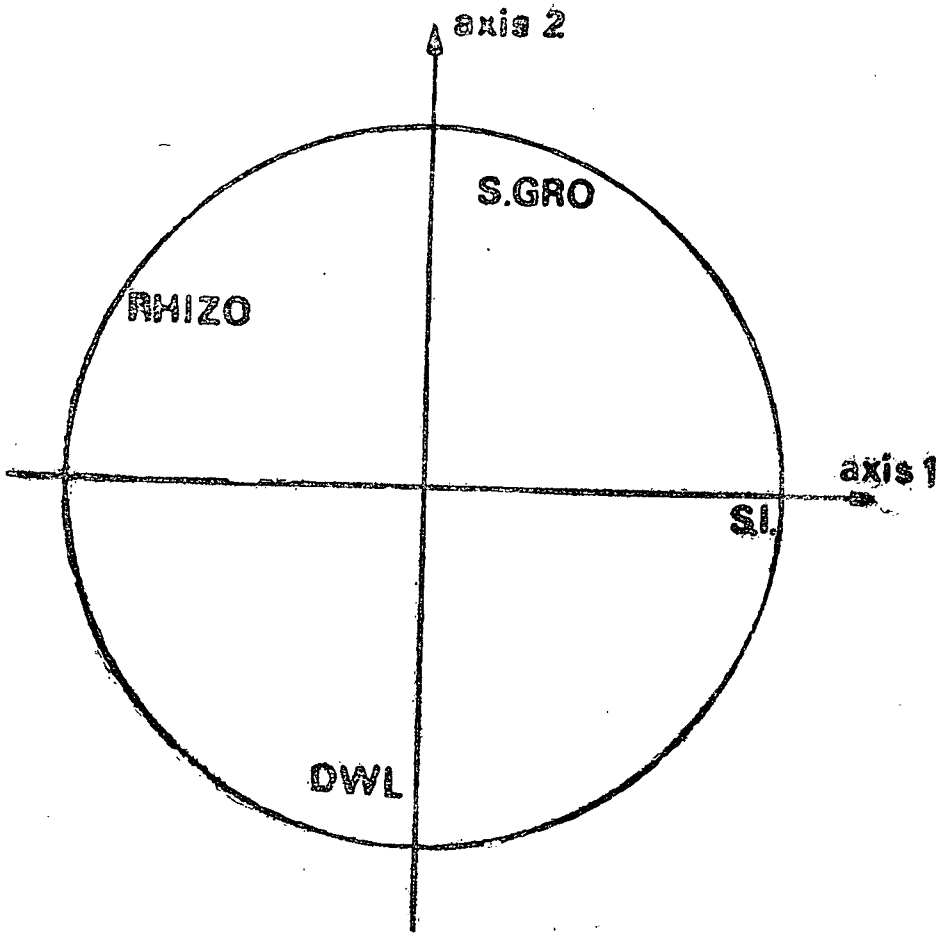

Fig. 4b. **Position of the variables on the correlation circle.**
DWL : difference in weight loss ; RHIZO : secondary rhizogenesis ; S, GRO : speed of isolate growth ; SI : severity index.

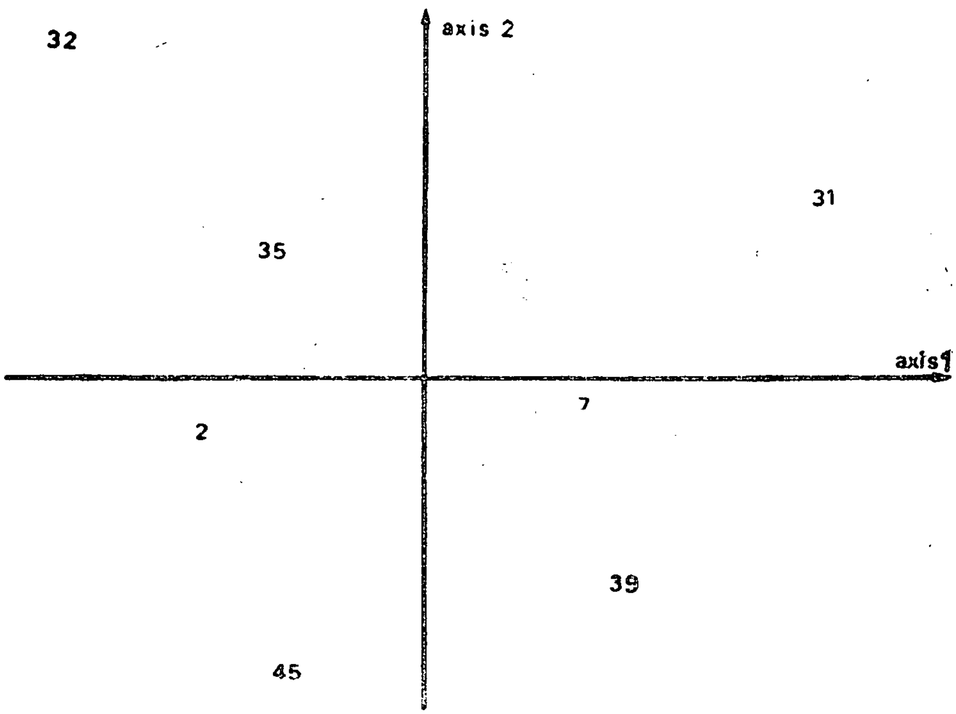

Fig. 5. Correlation between *in vitro* and *in vivo* characteristics of *Phellinus noxius* isolates.

Fig. 5a position of the strains on the plan 1 — 2 of the PCA. The most aggressive strains lie on axis 1 negative.

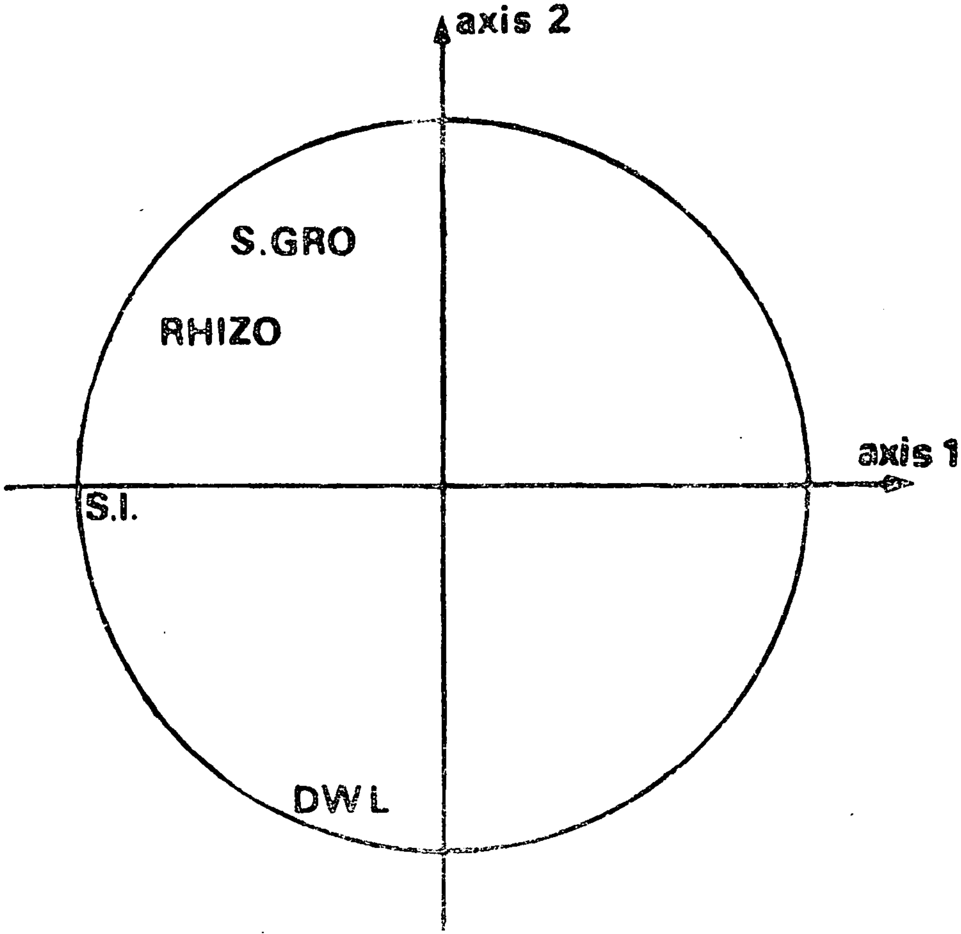

Fig. 5b. Position of the variables on the correlation circle.
DWL : difference in weight loss ; RHIZO : secondary rhizogenesis ; S. GRO : speed of isolate growth ; S.I. : severity index.

Table 6. *Comparison of* in vitro *and* in vivo *characteristics of* R. lignosus

Isolates (Stock n°)	Severity Index (S.I.)	Secondary Rhizogenesis (RHIZO) %	Speed of growth (S. GRO) cm/day	Optimum Temperature °C	Optimum PH	Δ Weight Loss (DWL)	Lignin Degradation (LIG)	α galactosidase (αGAL)	β galactosidase (βBGAL)	β glucosidase (βBGLU)	Pectinase (PECT)	Cellulase (CELL)
52	8,9	0	2,0	30	7,6	21,2	13	0	21,6	21,4	22,8	1
42	8,7	5	1,7	30	7,0	19,5	7,3	11,8	95,4	57,7	3,2	105
13	8,7	5	1,8	30	7,6	17,8	9,0	3,0	35,8	21,6	1,7	125
1	8,4	10	2,0	30	7,6	17,2	16,4	11,2	94,1	39,5	3,5	505
38	8,3	0	1,4	30	7,6	19,7	16,4	34,5	111,0	18,4	3,8	250
21	8,1	15	2,0	30	7,6	18,7	6,2	10,6	54,0	7,0	1,7	185
9	7,1	10	1,5	30	> 9 (?)	35,7	23,7	30,0	95,5	12,0	3,5	570
37	5,5	60	1,8	30	> 9 (?)	16,0	15,3	6,8	31,1	19,2	3,7	95

Table 7. *Multiple regression of the severity indexes of* R. lignosus *isolates explained by enzymatic characteristics, weight loss and lignin degradation of the blocks-test*

Variables Studied	Percentage of SI variation explained by	Correlation multiple coefficient "r"	F-value x	
β Gal. Pect. Cell., and Cat.	34,1 (a)	0,58	1,25	NS
β glu. α gal. Δ WL, and Δ LIGN.	32,4 (b)	0,57	1,19	NS

(a) S.I. = A + B, βgal - C.CAT + D.PECT — E.CELL.
(b) S.I. = A' + B'. ΔLIG + C'. ΔWL + D'. βGLU + E'. α GAL.

$$x \ \text{Fcal} = \frac{(n-3)\,r2}{2\,(1 - r2)}$$ with n = 8 and 3 degrees of freedom

F table = 8,35 at 5% confidence level

when individual hyphae were incapable of penetrating host roots. These observations are in contradiction with results obtained in our laboratory concerning the morphogenesis (Boisson, 1968) and the parasitic behaviour of the African isolates of this fungus. All the strains we studied in fact produce rhizomorphs, the contamination structure "par excellence", from which the penetration hyphae are differenciated. The differences in aggressiveness noted among strains are only manifested after the phase of root penetration, in the course of tissues colonization. This shows the absence of a relationship between rhizomorphogenesis and pathogenicity in the model in question.

Secondly, Liyanage *et al.* (1977) observed that the same highly aggressive strain was obtained in a region of Sri Lanka which was devastated by root diseases. In the Ivory Coast, on the other hand, no direct relation between the origin of the strain and its pathogenic capacity could be established, since there are considerable differences in aggressiveness among strains obtained in the same area (Table 5). Similar variability has been reported in the case of a population of *Armillaria*, whose individuals were isolated in a distance of less than 100 meters from each other (Redfern, 1975).

The reproducibility of the results, reflected by the low variations of the SI. of each isolate with time (Table 3), shows that experimental conditions of storage during the saprophytic stage and of greenhouse inoculations of the plants did not affect the pathogenic capacity of the strains. The pathogenic variations observed among these isolates may thus be considered as being constitutive of each.

We may now question the basis of this variability. In this context, attempts to correlate pathogenicity with the capacity of different strains to degrade plant polymers *in vitro*

Table 8. *Incidence and severity on rubber seedlings of* Phellinus noxius *isolates, collected in different areas from various hosts*

Isolates	RATING CRITERIA (*in vivo*)										*In vitro* characteristics	
(Stock n°)	Severity Index	Standard Error	Length Stem cm	Contamination %	Penetration %	Foliar Symptom %	Mortality %	Secondary Rhizogenesis %	Amount of Decay %	Location of Infection site	∆ Weight loss	Speed of growth cm/day
45	6,45	1,76	49	90	80	15	45	5	53	Tap root	46,8	1,8
32	6,2	1,3	59	95	95	5	35	25	24	Tap root	37,2	2,3
35	5,05	1,56	60	85	80	15	15	30	30	Tap root	36,3	1,8
2	4,54	1,9	62	65	65	5	20	25	16	Tap root	40,8	1,9
7	2,6	1,21	74	60	60	5	0	7	5	Tap root	38,8	1,8
39	1,5	1,3	74	35	30	0	5	10	5	Tap root	42,8	1,8
31	0,35	0,56	78	10	10	0	0	0	0	Tap root	35,9	1,9

means of 20 inoculated seedlings.

have not furnished positive results. This fact is also confirmed after assaying various enzymes (polyphenoloxidases and hydrolases) in the inoculum of each isolate before, during and after the experiment (unpublished data). Furthermore, several authors have also reported the absence of a correlation between saprophytic (*in vitro*) and parasitic characteristics (Raabe, 1967 ; James and Cobb, 1982 ; Worral, 1983).

We may invoke two hypotheses to explain this result :

— pathogeny does not depend only on the degradation of root structures. This would be suggested by some recent observations of young rubber plants killed by *R. lignosus* (artificial infection), whose tap root was only partially necrosed. We may thus reconsider the hypothesis of the participation of a fungal toxin in the infectious process already suggested by Peries, 1959 ;

— the saprophytic behaviour of these fungi, *i.e.* their capacity to degrade inert substrates, would not characterize the actual mechanisms utilized by the parasite to colonize its host. Extrapolation of results acquired on parasite behaviour *in vitro* would thus not be valid.

Other explanations have still been advanced to explain the variability existing among individuals (Prillinger and Molitoris, 1979) :

— a variation related primally to the stage of development of each isolate,

— a variation depending on the ecological conditions prevailing in the region in which the isolate originated,

— a variation caused by genetic differences.

The results described in the present article, in particular the stability of the pathogeny of a given strain with time and its variability recorded in a limited perimeter tend to prove that the third of the above hypotheses is the best adapted to explain the observed phenomenon. Thus, as reported for the genus *Armillaria* (Redfern, 1975), the African populations of *Rigidoporus lignosus* and *Phellinus noxius* would thus each constitute a mosaic of "clones" with different pathogenic potentials.

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A NEW METHOD OF DIRECT CONTROL OF *FOMES LIGNOSUS*,* CAUSING AGENT OF WHITE ROOT ROT OF *HEVEA*

By
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SUMMARY

White root rot of Hevea, *caused by the fungus* Fomes lignosus *presents a problem of particular severity in Lower Ivory Coast.*

The author has presented first the particular aspects of the disease in Ivory Coast : the environment, the pathogen, the damage. Then he has shown a new method of artificial inoculation which allowed to demonstrate good efficacy of Calixin against the parasite. Studies on the rate and frequency of application of the product have shown that by applying 10 g of Tridemorph, the a.i. of Calixin, per tree every 6 months, one can protect Hevea *trees very well from contamination with* Fomes.

Field trials, running since 3 years, have confirmed the efficacy of Calixin for direct control of the disease. Following these results, the plantations of Ivory Coast have applied this new method, consisting of detection of diseased trees (once per year) followed by 2 Calixin treatments per year of the diseased trees and their two direct neighbours in the line.

INTRODUCTION

Among wood destroying rots which attack cultivated plants and are prevailing in Ivory Coast, white root rot caused by *Fomes lignosus* is an important root disease of *Hevea* in the forest zone. This disease is a problem for *Hevea* cultivation in the country since 1953, when the first large scale plantations were established. It seems that the parasite has found nearly optimum conditions on the sandy soils of tertiary origin of Lower Ivory Coast. This applies both to its development and virulence : Crops cultivated on new cleared forest areas, rich in sources of primary infection (Chevaugeon, 1956; Delabarre, 1970) ; light top soil, medium high temperature, favourable rainfall and soil moisture mild dry season, host plant receptible and of little resistance.

Due to the position of the affected plant parts in the soil and the very solid structure of the rhizomorphs which propagate easily at greater depth, little was available until recently to control the disease effectively.

Since 1978 the " Service de Phytopathologie " of IRCA has concentrated its activities on research concerning this disease. The combined outcome of this research allowed to put forward a control method against *Fomes* which until now seems to show satisfactory results.

At first, peculiarities of the disease in Ivory Coast are described, in the following parts the different procedures are presented which allowed to recommend Calixin for the control of *Fomes* and its large scale application.

*The old name of *Fomes lignosus* is used for *Rigidoporus lignosus* throughout this paper.

The special conditions of Ivory Coast

The behaviour of the pathogen (growth and virulence) depend on the environmental conditions and on the reactions of the host plant which are again influenced by the environment.

The ecological conditions of Ivory Coast are given for comparison with other sites.

The environment

Root diseases are common in forest lands. The young *Hevea* trees are contaminated by diseased stumps of certain species which are found in dense forests of the "rain forest" type.

With regards to soil, all operating plantations are established in lower Ivory Coast, belonging schematically to two regions (Fig. 1) :

— In the southeastern region on tertiary sands with fairly uniform physical properties. These soils are distinguished by 10 — 15 % clay content in the topsoil, and 15 — 20% clay content in 1 meter depth. The average pH value is about 4·7 to 5·0, with minima of 4·0 and maxima of 6·0.

— Southwestern Region : The soils are slightly heavier with 25 — 30% clay in the topsoil and over 30% in 1 meter depth. The average pH is about 4·6.

The climatical data for the IRCA plantation, situated in the southeastern zone is summarized in Table 1. It shows two rainy seasons : The big rainy season in May - June and the small one in October and November. The average temperature is 26·3°C and the relative humidity is 86 6%.

The soil is saturated with water for the biggest part of May, June and July. It dries up during the small dry season in August and becomes wet again in October - November. From January to March the soil moisture content is progressively reduced.

In general, the ecological conditions are favourable for the spread of the disease, particularly the soil conditions appear to be almost optimal.

The Pathogen

Fomes lignosus is a fungus parasitic to the roots of a great number of woody plants, both growing wild and cultivated. In the forest, its parasitic role is limited. After role clearing, conditions become favourable for its development, and it attacks quickly the stumps of the felled trees. Each colonized stump forms a potential source of infection that threatens the planted *Hevea* in a circle of up to 40 — 50 m radius.

The disease spreads normally by means of mycelical filaments called rhizomorphs which develop on the roots of colonized host plants or simply by spreading through the soil.

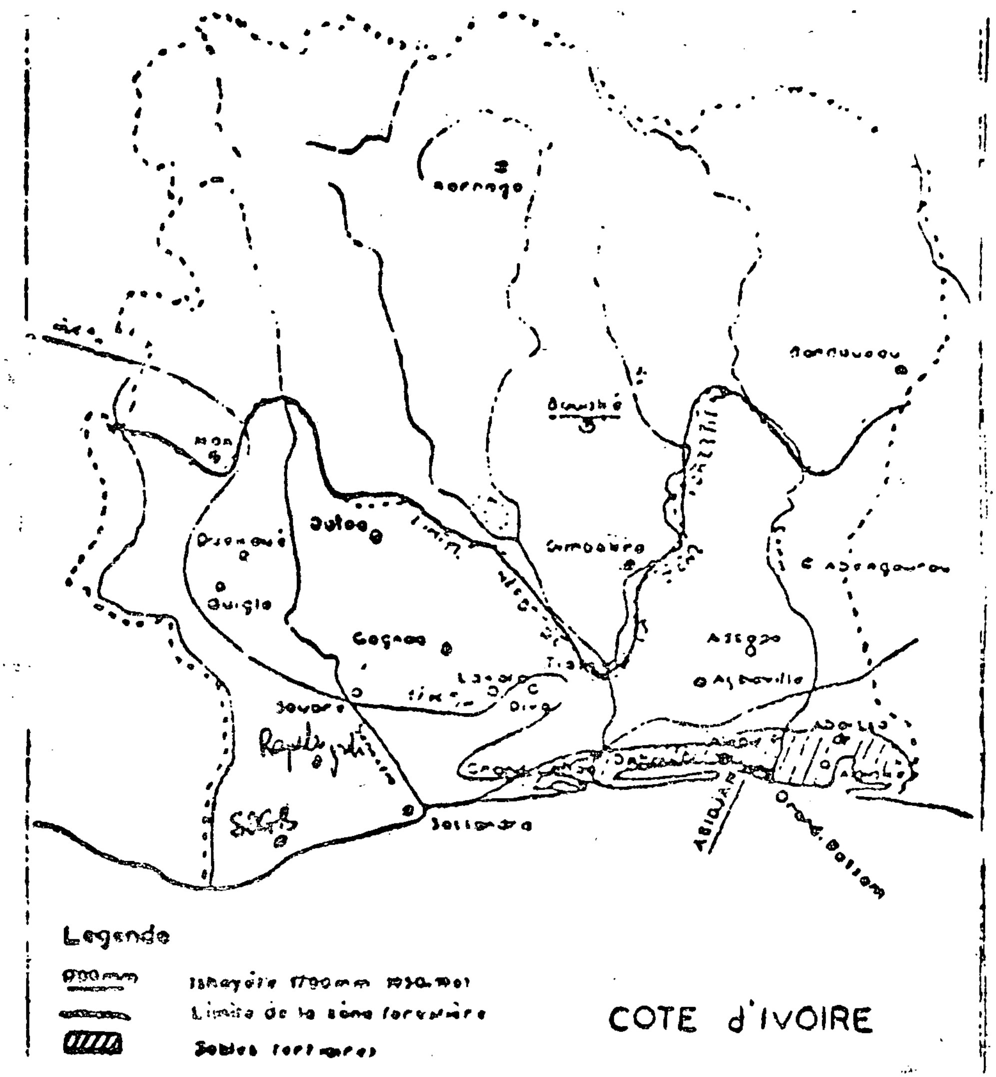


Fig. 1. Map of Ivory Coast.

Contamination of *Hevea* roots takes place by contact with roots of infected forest stumps. The extension of the source of infestation (foyer) and the duration of its activity depend on the size of the stump and its contents of nutritive elements which can be utilized by the parasite.

Symptoms : The symptoms of the disease develop with time : when the disease has reached an advanced stage, normally an off season flowering is observed. The leaves turn first yellow, then reddish brown and eventually fall off. Sometimes the tree refoliates, but the new leaves are smaller and lighter in colour.

At the same time of or following the wilting of the foliage, progressive die back of branches, forming of carpophores at the collar and eventually the death of the tree is observed. Often one can see also striate grooves (cannelures) on the base of the trunk of infected trees. This is due to the destruction of the main root, the function of which is replaced by lateral roots. These become very strong and lead to an asymmetrical form of the trunk base. In this case, the foliage normally remains healthy.

The symptoms of the disease have been precisely described by several authors and in different countrys where *Hevea* is grown.

In Ivory Coast, this has been done by Martin *et al.*, (1968). According to them, it seems that grooves at the trunk base are the first visible symptoms. Foliar symptoms (discoloration and leaf fall) are only visible at an ultimate stage.

The damage caused by *Fomes* is conspicuous after each cyclone. One observes that trees with obviously normal leaves are uprooted by the storm. An examination of the root system shows that the main root is rotten and broken 25 — 30 cm below the collar.

The Damage : The damage caused by *Fomes* can be seen early. From the end of the year of planting the first symptoms can be actually seen, but from the third year after planting the level of infection increases rapidly.

This is partly due to the extension of the root system of the *Hevea* trees, which multiplies the chances of contact with infected stumps, and partly due to the fungus which, after the forest had been cleared, has colonized a certain number of stumps and spreads by growing along their roots. Mortality increases from year to year until it reaches the maximum in the 6th year (6% annual mortality). After the 6th year, a decrease of virulence of the root rot can be observed, partly due to the disappearance of forest stumps, partly because of a large increase of root mass of the *Hevea* trees. Annual mortality diminishes and levels out at 1 — 2% (Fig, 2).

In later stages, the extension of the disease spreads out from spots which develop into clearing inside the plantation and which favour losses due to windbreak. Because of this, one can see in certain areas several clearings of more than 1 ha within a block of 25 ha (20 year old trees).

Table 1. *Weather data — Meteorological Station of IRCA ANGUEDEDOU*
Averages 1957 — 1983

Month	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total or mean
Rainfall in mm	36,3	74,5	103	150,4	245,1	571,5	241,3	57,7	91,5	156,3	136,9	70	1936,5
Mean temperature	26,8	27,4	27,8	27,6	26,9	25,1	24,3	24,5	25,3	26,5	26,8	27,2	26,3
Mean rel. humidity	82,1	82	81,6	83,1	86,5	91,1	89,9	87,5	88,3	86,4	87	85	85,6
Mean duration of sunshine in hours 74-83	180	162	171	179	150	90	78	54	72	117	174	162	1599

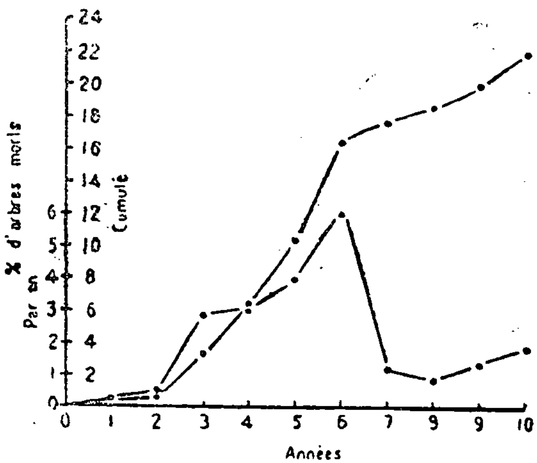


Fig. 2 : Development of the disease in relation to the age of Hevea trees (Martin et Col. 1968)

Fungicide efficacy test

The technique of artificial inoculation, the different treatments and the evaluation of the intensity of the disease are described below.

Selection and preparation of host plants

The *Hevea* plants are grown in an open air nursery. They are lifted at the age of 6 months. Only plants with a diameter between 1·0 and 1·5 cm are used.

They are trimmed to 35 cm length of the main root (pivot) and 30 cm of the stem. They are washed in water, and, after all rootlets were removed, planted into a container (A) filled with washed sea sand (surface : 1 m^2, depth : 50 cm).

The stumps so prepared are arranged around vertically inserted plastic tubes of 20 cm diameter, 10 stumps surrounding one tube and four tubes per container, representing four replicates (Fig. 3).

The plants are watered every 2 days : the first five times with pure water (100 cc/stump), the following with a nutrient solution (100 cc/stump) — for composition see Table 2.

Debudding is carried out regularly to allow only 1 stem to develop.

Table 2. *Composition of the nutrient solution*

Macroelements		Trace elements	
Salts	g/l	Salts	mg/l
$Ca(NO_3)_2\ 4H_2O$	0,590	$Mn\ Cl,\ 4H_2O$	1,80
KNO_2	0,505	$Cu\ SO_4\ 5H_2O$	0,18
$KH_2\ PO_4$	0,136	$Zn\ SO_4\ 7H_2O$	0,22
$Mg\ SO_4\ 7H_2O$	0,492	$H_3\ BO_3$	2,86
$NH_4\ NO_3$	0,200	$MO_7\ O_{24}\ (NH_4)\ 4H_2O$	0,26

Choice and preparation of the inoculum

Main roots (pivots) from 4 year old *Hevea* trees which have recently died from *Fomes* infection provide the natural inoculum.

After taking them out of the plantations they are washed, cut to size and then incubated in an other container filled with sand (B).

They are watered every 2 days for 3 weeks.

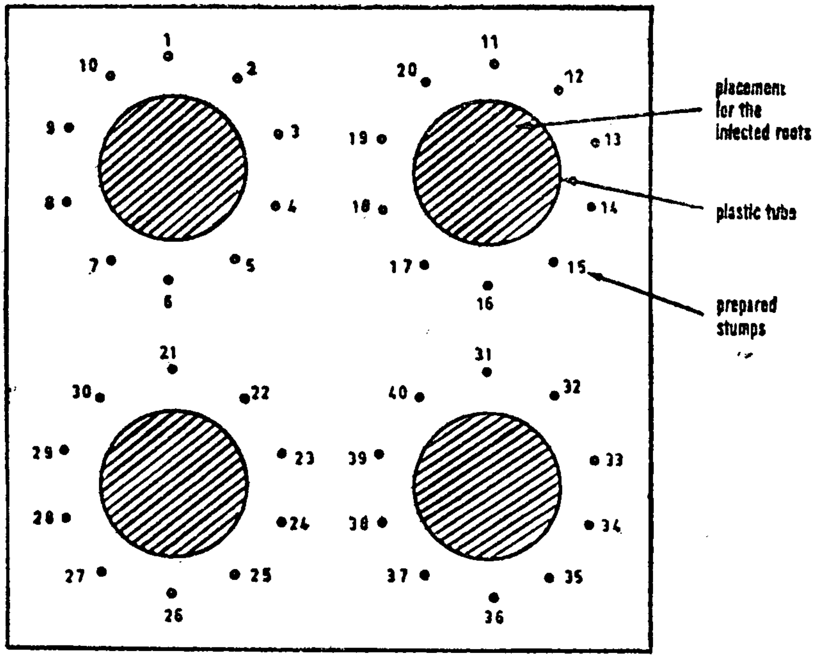


Fig. 3. Arrangement of the stumps around the plastic tubes.

Inoculation

Inoculation takes place when all young plants have at least one set of branches, approx. 6 weeks after transplanting into box A.

The plastic tubes are removed and replaced by the infected " pivots ", coming out of container B (Fig. 4).

Treatments

Two weeks after inoculation, the plants are drenched once with solutions of different fungicides. All plants of the same container receive 100 cc of same fungicide solution, poured around each stem base, 18 fungicidial formulations (Table 3) were tested at the same dose of 10 g active ingredient per liter solution (g.a.i./l). They were compared with an untreated control, giving a total of 19 treatments corresponding to 19 containers.

Table 3. *Fungicides tested. Concentration* : 10 g. a. i. *per liter water*

Commercial name	Active ingredient
Aliette (S)	Ethylphosphite d'aluminium
Arbotec (S)	2 - (4 - thiazolyl) benzimidazole * 5 g.m.a/l
Benlate (S)	Benomyl
Benodanil (S)	2 - iodobenzanilide
Calixine (S)	Tridemorphe
Cryptonol (S)	pentachloronitrobenzene
Derosal (S)	Carbendazine
Dowco 444 (S)	
BAS 38901 F (S)	Furmecyclox
Chevron 20615 (S)	Milfuram
Pelt (S)	methyl - thiophanate
Ridomil (S)	N° CGA 48988
Rovral (C)	Iprodione
Thiovit (C)	micronized sulphur
SICAROL (S)	Pyracarbolide
GALBEN (S)	Benalaxyl
SERINAL (S)	Dichlozalinate
TILT (S)	Propicanazole * g.m.a./l

(S) product with systemic action (C) product with contact action

* Concentration of 10 g a.i. per l caused the death of all plants due to phytotoxicity 3 weeks after treatment.

Evaluation of efficacy

Efficacy evaluation of the products is carried out when practically all plants of the untreated control are killed, approx. 6 months after inoculation.

Fig. 4. The tubes are replaced by " pivots " infected with *Fomes*.

Scoring of intensity of the disease is being done by means of a simple assessment system based on the state of the infection of the main root of the test plants. After up-rooting and splitting of the main root, each plant is classified ranging from 1—5.

Healthy plant : No trace of rhizomorphs on the bark of main root.

Contaminated plant : Rhizomorphs visible on the main root, tissue of the bark and wood healthy.

Infected plant : Rhizomorphs visible on the main root, with a quarter of the tissue necrotic (beginning of infection).

Heavily infected plant : Rhizomorphs abundant with half the tissue of the main root necrotic.

Dead plant : Rhizomorphs, tissues entirely necrotic.

An average score (N) is calculated for each treatment following the formula :

$$\boxed{N = \frac{\sum\left(\frac{\Sigma n}{p}\right)}{r}}$$

N — average score of 1 treatment (1 container)

n — score of each stump of the same replicate

p — number of plants of each replicate (10)

r — number of replicates per container (4)

Efficacy of a product is estimated partly by the average score (N) giving the incidence of disease development in one container and partly by the percentage of killed and infected plants.

Efficacy of a treatment is considered as good, medium or bad according to the average score (N) and the percentage of dead and infected plants (Table 4).

Table 4. *Determination on efficacy*

		% of the plants	
Efficacy	Average score (N)	Infected (dead or living)	Dead
Good	< 2·5	< 30%	< 30%
Average	between 2·5 and 3·5	30 to 50%	30 to 50%
Bad	> 3·5	> 50%	> 50%

Studies on rate and frequency of Calixin application against *Fomes.*

The same method of artificial inoculation was used with the following modifications:

— host plant : grafted stumps GT1, 20 months old

— substrate and experimental lay out : The stumps are planted into a concrete container open to the ground and filled with soil (dimensions : $1 \cdot 2$ m $\times$ $0 \cdot 9$ m). They are planted in groups of two. There are five groups per container (Fig. 5).

Treatments

For the trial " rates " : One week after inoculation, all stumps of the same container receive the same fungicide emulsion (Calixin) *i.e.* 1 litre around their stem base.

The rates are 4, 10, 20, 30 and 40 g active ingredient per litre emulsion, including an untreated control altogether six treatments with two replicates.

6 months after the first application, all plants are again treated as before.

For the trial " frequency " : The first treatment is made one week after inoculation. $2 \cdot 1$ of a $0 \cdot 5\%$ a.i. emulsion of Calixin are applied per tree. The different frequencies of application are : one single treatment, treatment every 6 months (twice per year), every 4 months (three times per year), every 3 months (four times per year), every 2 months (six times per year) and every month (12 times per year).

Evaluation of efficacy

The efficacy was evaluated after 12 months for " rates " and after 15 months for " frequences ".

Field trials

Objective of these trials is to limit the extension of sources of infection with *Fomes*. A plot of 25 ha of 4 year old *Hevea*, showing heavy *Fomes* damage, was selected. Detection was carried out by doing a very precise survey, tree by tree, with removal of the soil up to 15 cm depth around the collar and the lateral roots. Dead trees and those identified as infected (mycelium of *Fomes* visible at the collar and necrosis 10 cm below) were eliminated by extraction. Then the trees were classified into 3 groups.

— 1st group : trees known as contaminated with *Fomes :* mycelium is visible at the collar, but the main root at 15 cm depth is still healthy.

— 2nd group : trees with direct contact with a source of infection : healthy trees neighbouring trees contaminated with or killed by *Fomes* (1st tree on each side).

— 3rd group : trees with indirect contact with a source of infection (2nd tree on each side).

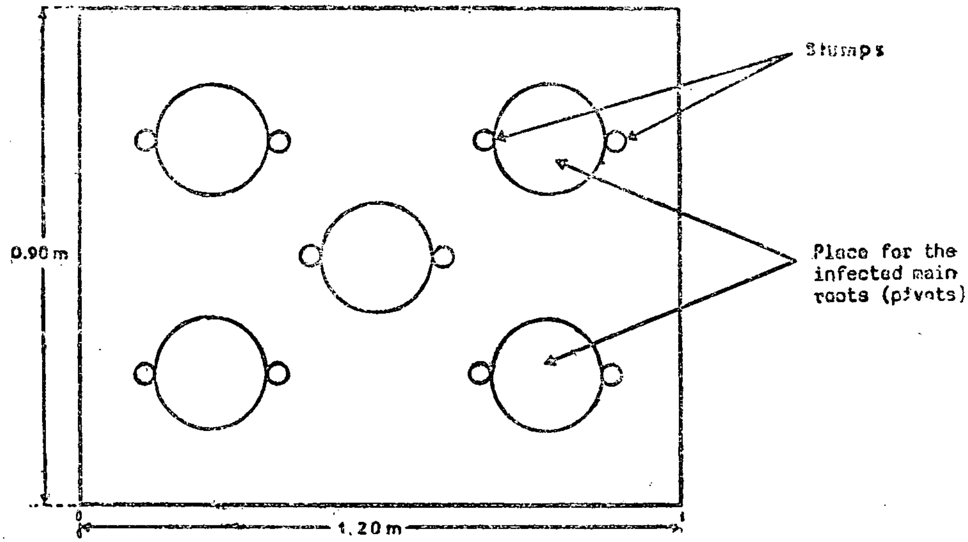


Fig. 5. Arrangement of stumps in a container.

The treatment consisted of carefully loosening the soil and forming a funnel like furrow (cuvette) around the main root, then pouring into this furrow 2·1 of a 0·5% Calixin emulsion. Treatments were first carried out at the commencement of the trial, then in the 6th and 12th month.

RESULTS

Efficacy test of fungicides

In the tests some cases of mortality were observed from the 3rd month after inoculation onwards : towards the 6th month more than 90% of the untreated plants (control) were dead.

The results are shown in Fig. 6 which indicates the "average score" (N) as well as the percentage of dead and infected plants for the different treatments.

After 6 months, practically all treatments showed 100% of the plants infected and more than 89% dead.

Only two products produced evidently lower percentages of infected plants than the other treatments : Rovral with 60% and Calixin with 10%.

— Rovral : With 60% of the plants infected, the mortality reached 35% ; its average score is 3·2. Its efficacy can be classified as medium to insufficient.

— Calixin : With 10% of the plants infected, and an average score of 1·3, this product can be considered as effective. In this treatment 12·5% of the plants were dead one month after application of the product, but no trace of rhizomorphs could be seen on the main roots. As the surviving plants showed a retardation of growth as compared with untreated controls, one is allowed to assume phytotoxicity.

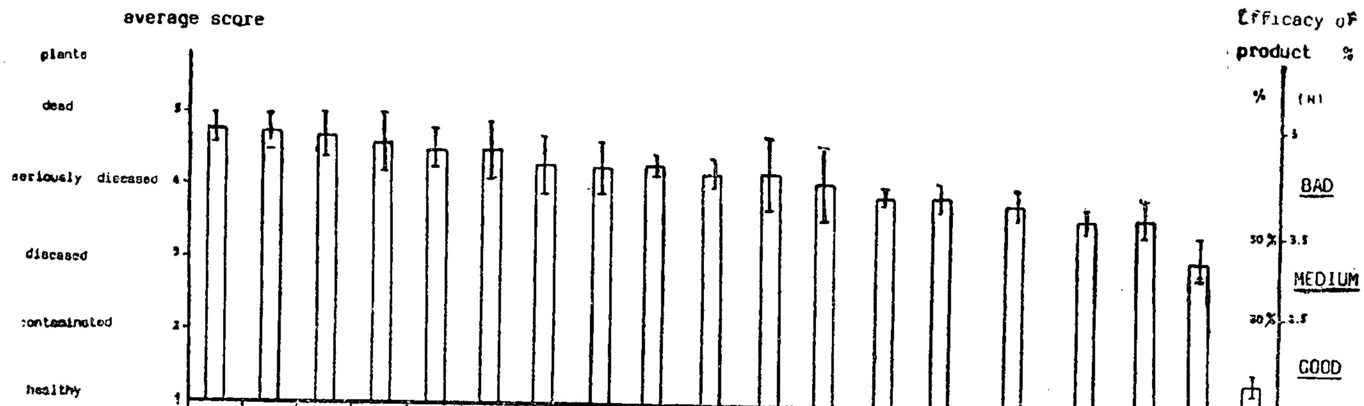
Studies on rate and frequency

The results are summarized in Figs. 7 and 8. These show the average scores and for each treatment the percentage of dead, infected, contaminated and healthy stumps.

One can see that the threshold of efficacy lies at 10 g a.i. per tree. At this concentration, the average score is 2·3 against 4·8 of the control, and the percentage of healthy trees is in the order of 50% which corresponds to "good" efficacy according to our system of evaluation.

Three months after the last application it could be stated that it needs at least 3 applications with 6 months interval to protect the stumps against *Fomes* attack.

Application every 4 months, 3 months and 2 months gives much better control, and only a monthly application can assure 100% protection. But at this frequency phytotoxicity is observed : The stumps are much less developed than those of the untreated and non-inoculated controls.



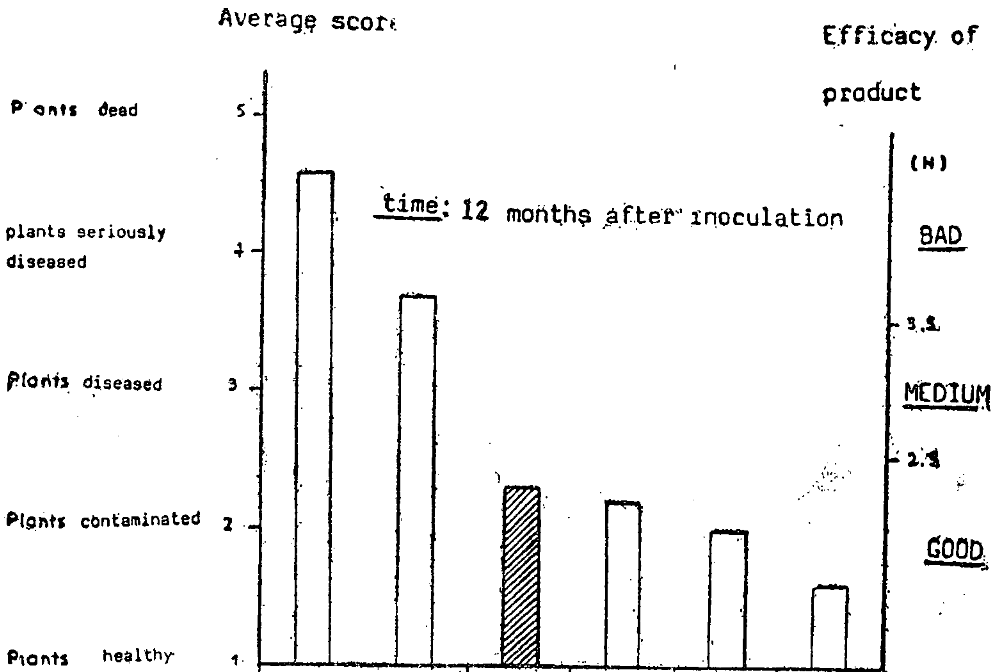
		Tomoin	Crypto-nol	Pell 44	Deniate	Deno-danil	Milfram	Arbotec	Thiviol	DALBEN
% of plants	infected	100	100	100	100	100	100	100	100	90
	dead	92.5	90.5	91.5	82.5	87.4	87.5	88.2	90.5	70

		DEROSAL	Ridomil	Alliette	TILT	SERINAL	ARBOTECT	SICAROL	Furme-cyclox	Rovral	Calixin
% of plants	infected	90	100	100	70	75	60	62	70	60	10
	dead	67	82.5	80.2	55	53	49	47	67.5	35	12.5 **

*) Percentage of total number of plants of each treatment.

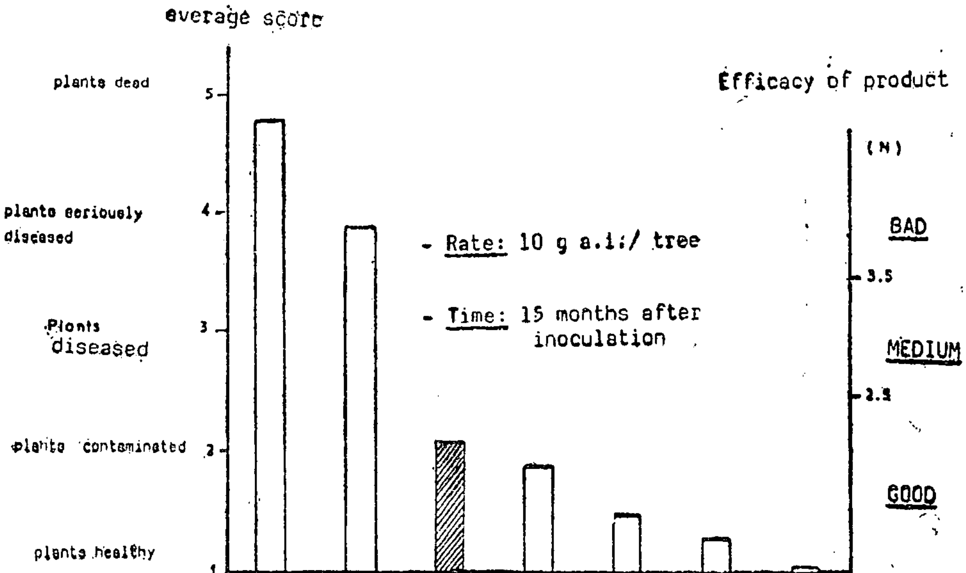
**) plants dead due to phytotoxicity

Fig. 6. Efficacy of fungicides against *fomes lignosus* plant artificially inoculated in vitro 6 months after inoculation.



a.i. rate m.a/ tree		control 0	4 g	10 g	20 g	30 g	40 g
n. of treatments		0	2 times: 1 week and 6 months after inoculation				
% of plants	dead	60	40	20	20	20	10
	infected	40	30	10	10	10	–
	contaminated	–	20	20	10	10	20
	healthy	–	10	50	60	60	70

Fig. 7. Trial rates of Calixio.



		control	1 single time	every 6 months	every 4 months	every 3 months	every 2 months	every month
no. of treatments		0	1	3	4	5	7	13
% of plants	dead	90	40	10	10	-	-	-
	infected	10	40	10	10	10	-	-
	contaminated	-	10	40	20	20	30	-
	healthy	-	10	40	60	70	70	100

Fig. 8. Trial frequency of application.

Field trial : Limitation of sources of infection

Six months after the third treatment, all trees of the experiment were examined for *Fomes*. The results are summarized in Table 5. According to these data, it can be stated :

— in the group of contaminated trees 43·5% of the trees are dead in the control against 12% of those treated with Calixin. 64·3% of the trees treated with Calixin have no rhizomorphs against 35·3% in the control.

— in the group of trees with direct contact with the source of infection, only 7·2% of the trees treated with Calixin became diseased against 32·8% in the control.

— in the group of trees with indirect contact with the source of infection, only 4·6% of the trees treated with Calixin became diseased against 20·5% in the control.

The results of this trial are remarkably similar to those of trials which were carried out at other places. They allow us to believe that by applying 2 1 of a 0·5% Calixin emulsion every 6 months, Calixin protects the trees very well against the contamination with *Fomes*.

DISCUSSION AND CONCLUSIONS

The aim of the method of artificial inoculation is to cause in relatively short time the highest possible mortality in the infected plants. To reach this, a strong inoculum (20 cm diameter) was used as compared with the size of the test plants (1·5 cm). Moreover, the distance between parasite and host plant is very narrow.

Death of plants was, therefore, apparent from the 3rd month after inoculation ; it reached over 90% towards the 6th month.

These results are in accordance with those of John who had shown that the capacity of the parasite to infect and to kill plants depends on the volume of the inoculum. The bigger the inoculum which serves as nutritive base of the parasite, the more is the incubation time reduced and mortality increased. This method permits thus to carry out rapid preliminary tests of the efficacy of a large number of fungicides against *Fomes*.

The use of sand as substrate assures good penetration into greater depth, on the other hand it eliminates the influence of different soil factors like micro-organisms and physical and chemical properties.

Among the products tested in our study, Calixin appears to be the most effective. We draw attention to Lim who has already shown its efficacy against *Fomes* by applying a mixture of Calixin and bitumen on the collar (" collar protectant ").

The results of the second series of trials gave us more precise information on the rates and frequencies of application to be used. The study has shown that by applying 10 g a.i. of Calixin per tree, 3 times with 6 month interval, one can protect the stumps against *Fomes* attack. This concentration and this frequency are, therefore, used in the field trials.

Table 5. *Results of field experiment* Fomes : *Limitation of sources of infection*

(a) *1st group* : Diseased trees : mycelium visible at the collar

treatment	diseased trees in Jan. 82	dead trees in June 83		trees remaining diseased in June 83		trees without trace of mycelium in June 83	
	number (N)	N	%	N	%	N	%
control	85	37	43,5	18	21,2	30	35,3
treated with Calixin 5 cc/l and 2 l/tree	84	10	11,9	20	23,8	54	64,3

(b) *2nd group* : Healthy trees in direct contact with source of infection

treatment	diseased trees in Jan. 82	dead trees in June 83		trees infected in June 83		trees remaining healthy in June 83	
	number (N)	N	%	N	%	N	%
control	131	6	4,6	43	32,8	82	62,6
Calixin	125	1	0,8	9	7,2	115	92

(c) *3rd group :* Healthy trees in indirect contact with source of infection

treatment	diseased trees in Jan. 82	dead trees in June 83		trees infected in June 83		trees remaining healthy in June 83	
	number (N)	N	%	N	%	N	%
control	88	3	3,4	18	20,5	67	76,1
Calixin	87	—	—	4	4,6	83	95,4

The results of the trials for limiting the sources of infection have confirmed that, at an interval of application of 6 months. Calixin has a good preventive action in the field.

Based on these results, all *Hevea* plantations in Ivory Coast have been treated with Calixin, using the following procedure.

— Detection and Marking (once per year, May - June - July)

A detection team of 5, led by a foreman, is responsible for 800 - 1 000 ha. Each man examines systematically each single tree by removing the soil around the collar and the lateral roots in order to search for the presence of *Fomes*. If he finds signs of the parasite, he marks the tree as follows : a red plastic band around the trunk of the diseased tree and a white plastic band on the two trees in direct contact, provided these are healthy.

At the same time, he prepares a funnel like furrow (cuvette) to accommodate the fungicide. Dead trees are marked with black plastic bands, they are eliminated by extraction.

The foreman follows the five men of the team and takes notes. For each line he records the number of trees which are dead, diseased or neighbours and have to be protected. Then he calculates the total number of trees to be treated in each block.

— Treatment (twice per year, July - August and December - January

After detection, another team carries out the treatment of the trees marked with plastic bands. The treatment consists of pouring 2·1 of 0·5% Calixin emulsion into the cuvette. Twice at 6 months interval.

This new method which is applied in Ivory Coast and Camerun since 1982 seems to give encouraging results :

In actual fact, in June 1982, the diseased trees of one plot were treated with Calixin after detection was carried out. In June 1983, we had among 76 diseased trees 8 dead ones (10·5%), 16 trees were still diseased (21·1%) and 39 trees which were free from mycelium (68·4%). From the 84 trees in direct contact, we observed three trees which became diseased (3·6%) and 81 which remained healthy (96·4%). From the 53 trees in indirect contact, only one single tree became diseased.

As compared with the traditional method of control (excavation + Fomac), the amount of hand labour required is considerably reduced. Actually, 80 — 100 trees can be treated per man-day, depending on soil conditions.

All the information accumulated in this experimental programme permitted to work out a control method which appear to be effective while its application is relatively easy. Although good and very encouraging, these results require long term confirmation : but considering the actual situation, one can hope to reduce effectively the losses due to *Fomes* by treating from the 2nd year until the 6th year after planting.

RUBBER ROOT ROTS : CELLULAR AND MOLECULAR ASPECTS OF HOST-PARASITE INTERACTIONS

By

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Host-parasite relations between *Hevea brasiliensis* and two African strains of wood rot fungi, *Rigidoporus lignosus* and *Phellinus noxius*, have been studied at both the cellular and biochemical levels. Aggression of the plant by each parasite, as well as the reactions elaborated against the diseases, are explained successively in detail in this publication.

Host aggression

Microscopic study

Observations were performed on young plants, 6 months old and infected artificially.

Penetration of hyphae into the tap root occurs via two distinct mechanisms :

— passive penetration : this occurs through natural openings and wounds. In the case of *R. lignosus*, the rhizomorphs exert pressure on the underlying tissues until they are dislodged, thus facilitating the introduction of the fungal filaments into the cortical tissues ;

— active penetration : each fungus causes the degradation of the periderm walls, after first perforating them. Intercellular spaces are also digested: in this case, host structures take on an alveolar appearance.

During this stage, *R. lignosus* exhibits the feature of differentiating haustorium-like structures which have never before been described for this species of fungus.

Colonization of cortical tissues is intimately related to the capacity of each fungus to degrade the walls of the host. Fungal filaments have thus been observed in intercellular, intracellular and interparietal positions. Regardless of the nature of the host walls (suberin, cellulose), the hyphae cause considerable damage. Some observations suggest the participation of fungal enzymes in this process :

— increased osmiophilia of the walls upon contact (or not) of the fungus ;

— a disorganization of the fibrillar structure of cellulose and suberin ;

— dislocation of the host cells.

A similar increase of the osmiophilic properties of the middle lamella precedes its perforation and complete digestion. This is particularly evident in the phloem, which is also the site of a particular disturbance to the rubber tree. Latice vessels undergo modifications under the effect of the infection, leading to the internal coagulation of the latexi Under the influence of metabolites, probably resulting from the degradation of the walls, the lutoid membranes burst. The resulting release of coagulating factors favours the gelling of the rubber into a mass.

Even though the degradation of non-lignified root tissues of the rubber tree is similar in the cases of attack by *R. lignosus* and *P. noxius*, it is nonetheless more rapid with *P. noxius*, as a result of the higher activities of its hydrolytic enzymes. The colonization and degradation of the wood, on the other hand, is greater with *R. lignosus*.

The hyphae of both *R. lignosus* and *P. noxius* penetrate the xylem via the parenchymatous rays. The vessels are invaded by either pits or after perforation of the walls. In this case, the filaments are inserted in the middle lamella by the initiation of microhyphae.

The degradation of vessel walls by *R. lignosus* generally begins at the level of the highly lignified fractions : the middle lamella and the primary wall. Under the action of the hyphae, the native structure of these cell components is disorganized, resulting in the appearance of a granular matrix, which is progressively perforated to form spaces. This erosion mechanism then spreads towards the secondary wall, whose S_2 layer is particularly deteriorated, in contrast to the S_3 layer.

The mode of xylem degradation by *P. noxius*, on the other hand, is not selective. There is a simultaneous attack on walls rich in either lignin or in polysaccharides. Apparently, no wall offers resistance to these fungal enzymes.

Biochemical studies

This line of research has been followed in order to determine the mechanisms of degradation of root tissues of rubber trees, as well as the differences in the enzymatic equipment which could explain the differences in behaviour between *R. lignosus* and *P. noxius*.

From a technical point of view, the analyses have been carried out on extracts from healthy and parasitized tissues, taken from young plants infected artificially or from tap roots of adult rubber trees infected naturally in a plantation. These studies have been extended by enzyme assays on culture filtrates from the two fungi. This procedure has enabled comparisons to be performed at several levels :

@ Healthy tissues/parasitized tissues : leads to an inventory of the metabolic changes which can be correlated with the parasitic attack.

@ Parasitized tissues/culture filtrates : comparison between enzymes detected *in vivo* and *in vitro*.

@ *R. lignosus*/*P. noxius* (extracts of parasitized tissues and/or culture filtrates) : specificity of the enzymatic equipment secreted by each parasite.

The main results are as follows :

(1) Compared to the enzyme activities which can be extracted from healthy tissues extracts from parasitized tissues exhibit a number of enzymatic modifications' both quantitative and qualitative.

(a) Quantitative : an increase — occasionally considerable — of the activity of certain glycosidases (beta-glucosidase, alpha - and beta - galactosidase,) esterases (acid phosphatase) and proteases (leucine aminopeptidase).

(b) Qualitative : These are enzymes activities not detected in healthy tissues : polyglycosidases (cellulase, xylanase, pectinolytic enzymes) and oxidases (laccase — p-diphenol oxidase).

(2) *R. lignosus* and *P. noxius* both excrete glycosidases, polyglycosidases and oxidases (laccases) *in vitro*, but at activity levels which are specific to each fungus. Thus there is a predominance of laccases in the case of *R. lignosus* and of hydrolases in the case of *P. noxius.*

These same quantative variations exist in parasitized tissues and are directly related to the nature of the pathogen responsible for the parasitic attack.

It is thus probable that the abnormally high level of certain enzyme activities in parasitized tissues, as well as *a fortiori* the presence of enzymes specific to them (polyglycosidases and laccases) are to be attributed to the pathogen colonizing the tissues. This hypothesis has been verified for certain glycosidases (alpha-galactosidase, beta-glucosidase) and for laccase and phosphatases : the enzymes (and isoenzymes) extracted from tissues parasitized by *R. lignosus* and *P. noxius* are in fact identical (starch gel electrophoresis) to the homologous enzymes excreted *in vitro* by each fungus, respectively.

(3) The enzymes secreted by the pathogens are well adapted to the degradation of plant tissues. The action of enzymes contained in culture filtrates causes the release of various saccharides (monomers and oligomers) from insoluble chips of *Hevea.*

Similarly, laccases must play a role in lignin metabolism. We have in fact been able to show that one of these enzymes (laccase L_1) produced by *R. lignosus* causes both the condensation and the depolymerization (*in vitro*) of lignin in the thioglycolic form.

What conclusions or hypotheses can we draw from these results ?

(a) Both parasites have enzymatic equipment enabling them to degrade both polysaccharide structures and lignin. All these tissues should thus be colonized by each fungus.

(b) Quantitative differences and especially the ratio of oxidative enzymes (laccase) and polysaccharidases should have an effect on the relative capacity (the rate) of the two fungi to degrade the different polymers of the walls, and thus the different root tissues. In practice, it is expected that *P. noxius* is more active than *R. lignosus* on polysaccharide structures and thus in tissues which are richest in cellulose, xylan and pectinic materials, and the inverse should be true of highly lignified tissues.

The comparison of lignin contents between healthy and parasitized tissues confirms that — in a general manner — both fungi can degrade both the polysaccharide fraction of these tissues and lignin. These results also agree with data obtained *in vitro* in trials of degradation of previously sterilized sticks of rubber tree wood.

Histological studies have contributed more detail to this result, by the direct observation of the tissue degradations described above. In agreement with biochemical data, it would seem that *P. noxius* degrades cortical tissues more rapidly and more completely than *R. lignosus*, as a result of its very active hydrolases which are excreted. The latter fungus similarly degrades the woody lignin-rich structures more rapidly (primary wall, S_1 and S_2 layers of the secondary wall) than the structures composed primarily of polysaccharides, *i.e.* the S_3 sublayer. *P. noxius*, on the other hand, degrades xylem substructures in an equivalent manner, regardless of their chemical composition.

This latter observation is in apparent disagreement with biochemical data. It is nevertheless probable.

— that the enzymatic equipment leading to the degradation of lignin is not a limiting factor in the invasion of the xylem by *P. noxius* ;

— that — on the contrary — the battery of hydrolases which are deficient in *R. lignosus*, limits the potentials of this parasite.

This hypothesis presents the interests of accounting for both the histological and biochemical data. It nontheless remains to be verified.

Reactions of the host

Numerous reactions elaborated by rubber trees have been characterized at all the stages of the infectious process of each parasite. Our own work has been carried out at the anatomical, cellular and molecular levels. The reactions are described in the order of their appearance during the infestation.

Early reactions. They occur at the initial stages of penetration. The most characteristic of these reactions is a hypertrophy and hyperplasia of young differentiated cells of the phellogen. This mechanism is often initiated around one or two necrotic cells, raising the possibility of hypersensitivity. Cytological tests carried out in parallel have shown a stimulation of the pool of phenolics localized under the points of penetration.

Post-initial reactions. These reactions are elaborated during the penetration and nvasion of the first cell layers. The most consistently occurring of these reactions in *Hevea* is most certainly the increase of cell layers under the points of penetration. It results from a stimulation of the activity of the cork cambium. The walls of certain cells thicken concomitantly. The identification of the nature of this thickening showed that it was composed of suberin or lignin.

Reactions occurring during the colonization of tissues. All tissues, whether or not they are lignified, are involved by these reactions. In the young cork, for example, some cell walls are deformed, taking on a notched appearance. Microscopic observation has revealed wall appositions in the periplasmic space of the cells. When examined under ultraviolet light, these deposits fluoresce and are thus probably composed of callose. Similarly in the phloem, clumps of callose obstruct the pores of sieve tubes.

In the region of the xylem, the lignification process becomes heterogeneous. Cell islets are differentiated before the cambium in the young phloem probably in order to slow down the progression of invading hyphae. This is also the role of the tyloses which obstruct the water bearing vessels of the wood. In addition, some of these vessels present a " new wall ", laid down in the lumen in contact with the S_3 layer of the secondary wall.

Late reactions

The anatomical organization of the *Hevea* tap root is occasionally disorganized by the differentiation of new tissues. We can thus distinguish :

— meristematic - like tissues initiated from the parenchymatous rays of the xylem. The organization of the cell foci is reminiscent of that of a meristem ;

— phloem and ligneous tissues, set in place by a neocambium. Native diseased tissues are rejected towards the exterior or are isolated from the rest of the root. In greenhouse conditions, 10% of the plants infected with *R. lignosus* exhibit this phenomenon. It is probable that it is identical to the mechanism initiating healing callus formation in adult trees naturally infected.

At the biochemical level, there is a considerable change in the spectrum of isoperoxidases which can be extracted from different types of tissues. Healthy tissues are characterized by the presence of numerous isoenzymes, while reacting tissues and especially parasitized tissues from adult tap roots (the phenomenon seems to be less specific in young subjects) are characterized by the presence of one major isoenzyme. In the most typical cases, its activity accounts for almost 100% of total peroxidase activity and corresponds to the stimulation of the homologous isoenzyme of healthy tissues by a factor of 100.

This enzyme polymerizes coniferyl and p - coumarilic alcohols into insoluble products (DHP — dehydrogenative polymerisates) whose chemical structure is analogous to that of lignin. It is thus possible that this peroxidase contributes to an abnormally elevated lignification of certain tissues, leading to the construction of a barrier, whose purpose is to prevent the intertissue progression of the fungus. This type of wall thickening has in fact been observed.

Is this an early or late process ? Our results are consistent with it probably being an early reaction : healthy tissues close to the front of parasite progression already seem to be the site of an analogous disturbance, although of lesser amplitude.

The lignin contents in different tissues studied would tend to confirm this hypothesis. Healthy tissues close to the front of parasite progression and above all the infected tissues taken from this front of progression have an abnormally high lignin content. It may be supposed that parasite invasion causes the host to react by lignifying. This reaction is, however, ineffective, since these tissues are subsequently degraded.

In the case of infection by *P. noxius*, the host reaction is reduced, both in terms of peroxidase synthesis and lignification. This absence of reaction may be compared to the rapidity of the intertissue progression of the fungus.

The global efficacy of all these reactions does not enable *Hevea* (GT1 clone) to resist attack by *R. lignosus* and *P. noxius*. When considered individually, however, certain of these reactions prevent the spread of hyphae in the tissues, which is the case for the cellular hypertrophy and hyperplasia and the supernumerary cortical cell layers under the points of penetration. Other reactions, on the other hand, are apparently much less effective, *e.g.* lignification and suberin synthesis of walls or callose deposits (wall apposition). Each of the parasites possesses enzymes which can degrade them.

On the other hand, tissue neogenesis eliminates diseased tissues. No contamination of new root structures has been observed after this process. This mechanism assures the survival of the plant, which assumes normal growth.

The comparison of these defense mechanisms with the CODIT (Compartmentalization of Decay in Trees) model shows, among other thing, that the process of tissue neogenesis is equivalent to wall 4 of this model. The purpose of this barrier is to prevent the spread of decay to differentiated tissues after the parasitic attack. Finally, the compartmentalization mechanism of wood rots, already described in the case of other ligneous plants parasitized by other wood rot agents, is also applicable to the host parasite couple *H. brasiliensis* / *R. lignosus* and *P. noxius*.

AN INTEGRATED APPROACH TO CONTROL OF WHITE ROOT DISEASE IN SRI LANKA

By

A. de S. LIYANAGE, O. S. PERIES, S. S. WARNAPURA, E. A. T. SENADEERA AND W. AMARATUNGA

ABSTRACT

White root disease caused by Rigidoporus lignosus *can be controlled at three stages of cultivation of rubber viz. pre-planting, planting and post-planting. In the first stage, it is essential to demarcate infected patches encompassing three to four rows of trees bordering infected patches and three to four rows of stumps buried closest to the perimeter of infected patches. Removal of most of the infected roots as practicable and burning them in situ is advocated. Changing the planting distance between replanting cycles has helped to reduce the incidence of white root disease in the new clearing. Creeping leguminous covers enhanced the decay of root debris, encouraged the growth of antagonistic flora and dissipated the highly inocuous infected roots into ineffective ones. At planting, sprinkle 114 g of sulphur around each plant. Application of sulphur should be confined to plants in demarcated patches where infected trees stood in the old stand. Amendment of soil with sulphur helped to reduce the* p^H *for periods up to 18 months and encouraged the growth of* Penicillium *and* Aspergillus *species which were antagonistic to* R. lignosus. *Sprinkling sulphur on the surface was as effective as mixing it with the soil but the latter was more expensive. At post-planting, detection of infected trees by foliar symptoms was confined to demarcated patches. This helped in the early detection of infected trees. The application of Collar Protectant (Pentachloronitrobenzene) on the roots of neighbouring trees prevented further spread of the disease. Preliminary experiments have indicated that drenching the soil with Calixin (tridemorph) has helped to kill the superficial strands of the mycelium on roots of trees in early stages of infection. The possibility of using some selfed clonal seedlings as resistant root stocks is also discussed.*

INTRODUCTION

White root disease (WRD) of the rubber tree, *Hevea brasiliensis* Muell. Arg., caused by the fungus *Rigidoporus lignosus* (Klotzsch) Imazeki is the most destructive root disease in Sri Lanka. Rubber trees of any age or vigour succumb to the disease, killing them directly, bringing about the largest number of tree losses in the rubber plantations (Liyanage, 1977). Several reasons could be attributed to the widespread occurrence of WRD in Sri Lanka. The insidious nature of the disease is often not realised until after it has become well established in the plantation. Also, there is a tendency to neglect the treatment of root diseases because the benefits of control are not immediately felt. This is further aggravated by the suspension of control measures during periods of financial difficulties (Fox, 1977). The damage caused during the immature period results in the reduction of the stand leading to a lowering of the production and therefore, the export earnings from rubber which accounts for nearly 11% of the gross national income. The advances in research made over the last two decades have led to the development of more efficient and economic methods of control. Yet, the disease has not been satisfactorily controlled mainly due to the negligence of growers.

This paper examines the present status of WRD in Sri Lanka and discusses how cultural, biological and chemical methods are used singly and in combination to combat its spread.

EXPERIMENTAL

Extent of damage

Disease incidence : Several rubber estates covering an extent of 2128 ha were surveyed in 1977 — 78, to assess the extent of damage caused by *R. lignosus*. The damage was higher in Ratnapura, Kelani Valley, Kalutara and Galle regions. The infection was lower in the drier areas of Kurunegala and Matale (Table 1).

Table 1. *Damage caused by white root disease in different rubber growing areas*

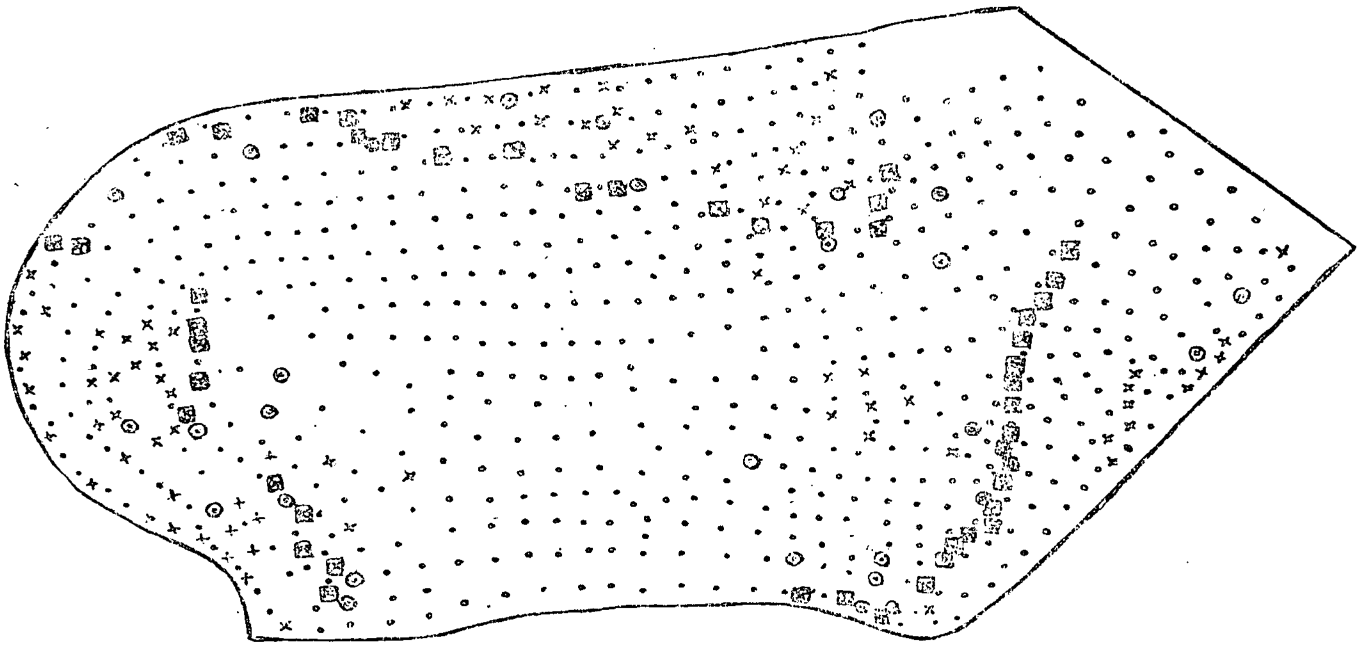
Areas	Extent of damage (%)
Ratnapura	8·9
Kelani Valley	8·4
Kalutara	7·0
Galle	6·6
Kegalle	4·8
Kurunegala	1·5
Matale	0·3

When the clearings of all areas surveyed were grouped according to their age, it was shown that the incidence was low in the first 5 years of growth but steadily increased to reach a peak in the 20 — 25th year of planting or just before uprooting. A recent estimate of WRD incidence was not made in the smallholdings, which occupies nearly 70 percent of the total area under rubber. However, Wijewantha (1964) showed that the highest infection occurred during the first 3 years in a replanting, after which there was a drop in the rate of infection.

Pre-planting methods

Disease demarcation : New centres of infection in the replantings arise from the infected root debris left in the soil. These usually occur at the border of large open confluent infected patches of the old stand, or close to infected trees of the original stand if the disease occurs in small or isolated patches (Fig. 1).

Infections in the replanting rarely originate from the centre of infected patches, as most of the stumps have decayed beyond the stage which can support the growth of the pathogen. However, upto four rows of stumps usually buried in the soil, closest to the patch were shown to harbour the pathogen, roots of trees bordering the periphery of patches showed the least amount of decay and contained highly viable inoculum. The remaining stumps, lying towards the centre of patches, showed a progressive increase in the decay and a decline in the viability of the inoculum. Similarly, the roots of up to four rows of apparently healthy standing trees round infected patches were infected with *R. lignosus*.



- ✕ . STANDING TREES IN THE ORIGINAL STAND.
- ▩ INFECTED TREES IN THE ORIGINAL STAND.
- ∘ NEW PLANTING POINTS.
- ⊙ NEW INFECTION.

Fig. 1. Sites of new infections in the replanting in relation to the infected debris in the old stand.

The actual number of infected rows of trees and stumps varied depending on the planting distance. The spread was greater if the inter row space was closer and less if it was wider as in the avenue system of planting. The clearings in experiments done during the period 1975 — 78 (Liyanage, 1976, 1977 and 1978) did not show any new infection sites in areas which had healthy trees in the old stand, except when infected stumps were introduced to these areas by rolling them down the slopes during the process of land clearing.

Therefore, the area to be replanted must be carefully inspected to demarcate all infected patches prior to uprooting the old stand, encompassing 3 — 4 rows of apparently healthy trees and 3 — 4 rows of stumps buried in the soil towards the centre of the patches. This helped to identify the areas containing active sources of inoculum, so that special attention can be paid to eradicate them.

Uprooting the old stand : This entails removal of rubber trees in the old stand, to ensure that little or no infected roots are left in the soil as it was recognised that infection can arise only by root contact (Petch, 1921). The mycelium of *R. lignosus* did not survive in the soil, when removed from its food base (Bancroft, 1912) and it did not cause infection except from a large piece of infected root, as it is a weak parasite (De Jong, 1933). The results of a number of experiments reported by Fox (1961b), indicated that complete eradication of roots was uneconomic when considering the number of trees saved. However, under Sri Lankan conditions Peries (1963 ; 1974), showed that removal of all the potential sources of infection was essential when the incidence of WRD was high in the old stand. More recently, Liyanage (1978) laid out several field experiments to examine the methods of clearing land prior to replanting.

The distribution of roots in trees at different soil depths was examined. It was observed that 90% of the lateral roots of rubber trees were present within the first 60 cm soil depth (Fig. 2).

The roots within this region were usually larger than those below this region. A high percentage of the infected roots were also present in the upper 60 cm layer of soil. The tap root length varied (range 107 — 262 cm) according to the soil condition, type of clone and other factors but the mean length of those measured was 158 cm. The mean length up to which the infection was detected ranged from 91 — 186 cm with a mean of 125 cm.

Table 2. *Distribution of lateral roots at different soil depths*

Type of root	0—30 cm	31—60 cm	61—90 cm
Total (%)	70·1	20·1	9·8
Infected (%)	65·9	24·4	9·7

These observations have helped to identify the area in which active sources of inoculum were present, so that proper attention can be paid to remove as much of the large pieces of inoculum as practicable, within demarcated patches. All infected roots must be collected and burnt preferably *in situ*, to prevent accidental introduction into areas hitherto free of the disease.

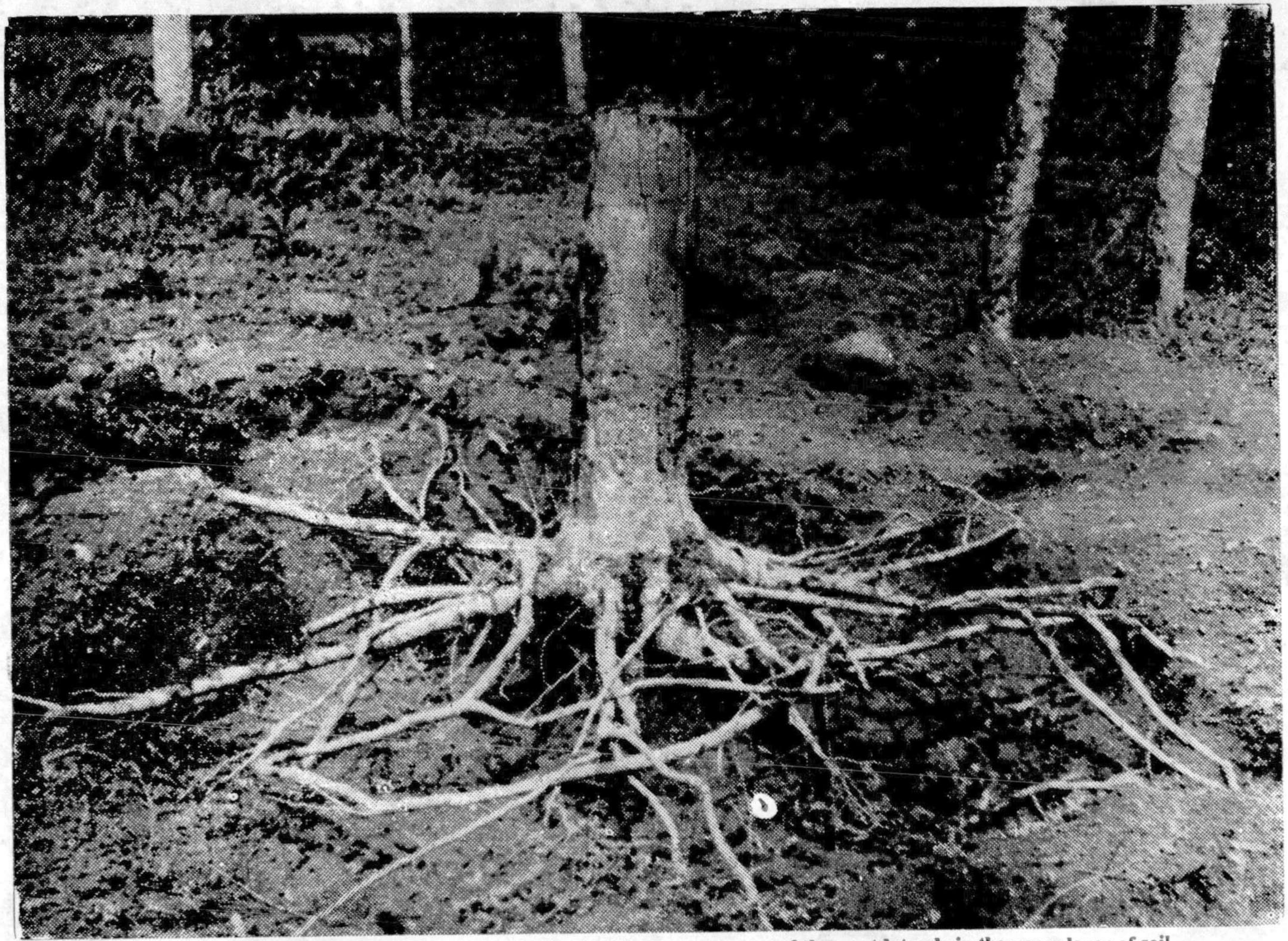


Fig. 2. Distribution of lateral roots in a rubber tree. Note the presence of the most laterals in the upper layer of soil.

When different sizes of roots of a standard length were buried in planting holes, the small roots (<0·6 cm diameter) lost their viability in 6 months and failed to cause infection of rubber plants. However, larger laterals viz. 1·2, 2·5 and 5·0 cm diameter, caused 20%, 40% and 80% infection, respectively, within 1 year of their placement in the planting hole (Table 3).

Table 3. *Effect of size of inoculum in the planting hole in infection of rubber plants*

Inoculum diameter (cm)	Infection (%)
0·6	0
1·2	20
2·5	40
5·0	80

At this stage, most of the 2·5 and 5·0 cm diameter inocula remained viable. When infected stumps or large laterals were placed at a distance of 180 and 60 cm respectively, away from the plants in the row, infection occurred in the plants adjacent to inocula in 18 months.

The superiority of uprooting the infected sources, as compared to leaving unpoisoned stumps cut at ground level, was evident from results shown in Table 4.

Table 4. *Effect of methods of clearing on tree losses under different covers, 5 years after planting*

Method of clearing	Tree losses (%) Naturals	Tree losses (%) Legumes
Stumps uprooted and burnt	2·7	2·5
Stumps uprooted and stacked	2·5	2·9
Stumps cut at ground level (not poisoned)	6·3	7·8

The process of decay in untreated stumps was slow. When diseased trees were cut at ground level, the parasitic activity was increased making the stumps active sites for transmitting the disease to trees in the new stand, until they have become moribund.

The steep terrain in Sri Lanka precludes the use of expensive mechanical clearing methods, because of the high risk involved in exposure of soil to erosion, although it is a recommended practice in Malaysia (Newsam, 1964).

Poisoning methods : Sodium arsenite was used by Napper (1939) to poison the old stand of rubber at the time of clearing land. This was replaced with the 5% butyl ester of 2, 4, 5 - T in diesolene, and it was significantly better than sodium arsenite in enhancing the decay of rubber trees or stumps (Newsam, John and Rao, 1961).Tree poisoning was superior to stump poisoning (Hutchinson, 1961 ; Fox, 1961a). The freshly cut surfaces of stumps were prone to infection by the wind-borne basidiospores (John, 1964 ; Lim, 1976), and the application of creosote, a wood preservative, on the surface of stumps inhibited spore colonisation. The use of this clearing procedure was discouraged in Sri Lanka (Young, 1964). Later, a series of experiments were conducted by Liyanage (1975), in highly infected and uninfected clearings, located in wet rubber growing districts and in slightly infected areas in the dry districts. These trials were conducted to test the efficacy of some chemicals on stump decay viz. urea, borax, 2, 4 ,5, - T in diesolene, with uprooting and burning stumps and leaving untreated stumps as controls. It was observed that 2, 4, 5 - T induced decay markedly faster than the rest of the chemicals and the untreated controls. Although application of creosote to the cut surfaces was aimed at preventing infection through basidiospores, none of the untreated stumps were infected in this manner. Poisoning the stumps could not eliminate the disease from infected trees. When the old stand was free of WRD, new infection did not occur in the replantings located in the wet districts. Stumps of trees already infected, transmitted the disease to new plants, irrespective of the treatment to which they were subjected. Infected stumps left in the soil of the old stand gave rise to new infections in replantings of both wet and dry areas.

Poisoning trees of the old stand was not included as a treatment as the falling branches or trees could damage the immature trees and also it would incur an additional cost, to remove the debris.

Altering the planting distance : Changing the planting distance between replanting cycles, a method hitherto not attempted, as a means to control WRD, has resulted in an early reduction of the incidence of the disease in the new clearing (Table 5). Preliminary observations recorded an year after planting indicated that losses were higher when the planting distance was the same or similar to that of the original stand, even when the infected sites in the old stand were relatively low (viz. 31%). There was a reduction in the infection when the interrow space was increased, although the number of potential sites of infection was high (viz. 43·4%).

Table 5. *Effect of planting distances on tree losses after one year*

Planting distance (m)	Infected trees* in the old stand (%)	Losses in the new stand (%)
4·6 × 4·9**	46·9	2·6
3·6 × 6·1	32·3	1·6
3·3 × 7·3	31·0	2·5
2·4 × 9·1	43·4	0·3

* Includes infected trees and vacancies due to death of trees

** Planting distance of the original stand

Cover crops : The beneficial effects of creeping leguminous covers and the undesirable effects of woody shrubs as indicators of potential foci of infection have been reviewed (Hutchinson, 1961 ; Fox, 1961 b, 1965a, 1971, 1977 ; Liyanage, 1980). The fungus freely infects the roots of covers encouraging its spread but not necessarily the disease. In the process of dissipation of inoculum they get diffused into small ones which are less dangerous and ineffective. Covers also provide an environment which encourage rapid decay of roots and timber by saprophytic organisms, causing them to exhaust their food reserves (Fox, 1961a, 1956a, 1977).

Evidence that creeping leguminous covers reduce the incidence of WRD in replantings, compared to the naturals (a mixture of grasses and legumes) could not be established. This was because legumes were more abundant than grasses in the mixture. However, the decay of roots was accelerated beneath the pure legume covers. The activity of *R. lignosus* was considerably reduced when it was grown on soils taken from under a cover of *Pueraria phaseoloides* (Table 6).

Table 6. *Growth of* R. lignosus *on soils obtained beneath* Pueraria *and clean weeded soil under laboratory conditions*

Type of cover	Mean rhizomorphs No.	Mean length of distinct rhizomorphs (cm)
Pueraria phaseoloides	1·2	2·2
Clean weeded soil	4·6	5·6

However, the number of rhizomorphs and their length showed different patterns when grown on different soil types, collected under a cover of *Pueraria* (Table 7).

Table 7. *Growth of* R. lignosus *on four soil types collected beneath a cover of* Pueraria, *under laboratory conditions*

Soil series	Mean rhizomorphs No.	Mean length of rhizomorphs (cm)
Boralu	3·3	2·0
Ratnapura	4·4	2·2
Agalawatta	5·3	2·9
Matale	5·5	1·7

Planting methods

Soil amendment : The use of sulphur (114 g) as a soil amendment in the planting hole, to reduce the incidence of WRD was first demonstrated by Peries (1965, 1966, 1972). Later, Satchuthananthavale (1971), Liyanage (1980), confirmed the earlier findings of Peries.

Liyanage (1980) showed that the application of 114 g of sulphur at the time of planting was effective in reducing new infections in the replanting, especially when most of the large infected roots of the old stand were removed. The number of infections increased in the absence of sulphur and inadequate removal of inocula, but in its presence losses were markedly reduced (Table 8).

Table 8. *Effect of removal of infected roots and application of sulphur or tree losses after 18 months*

Treatment	Cumulative losses (%)
+ G + S	0
+ G — S	1·2
— G + S	0·5
— G — S	4·7

+ G = roots removed
— G = roots left in the soil
+ S = 114 g sulphur applied
— S = sulphur not applied

A sharp decrease in soil pH was recorded 3 months after the application of 114 g and 228 g of sulphur, the latter being slightly more effective than the former (Fig. 3).

The increase in acidity was accompanied by a concomitant increase in the species of *Penicillium* and *Trichoderma*. The population of the latter nearly doubled at the soil surface while that of *Penicillium* declined but recorded a sharp increase at 15 and 30 cm depths. There was no change in the fungal population of *Aspergillus* and several unidentified species (Liyanage, 1980 ; Liyanage, Peries and Liyanage, 1983). They also observed that some of these fungal species can cause lysis of the mycelium of *R. lignosus*, showing their antagonistic activity.

Sprinkling of sulphur and forking it into the soil after planting was cheaper than mixing it with the soil before planting or mixing 57 g of sulphur with the soil of the lower half of the planting hole and sprinkling the balance on the surface, after planting (Liyanage, 1980). Most of the roots were confined to the planting hole up to about 6 months after planting. In 12 months most laterals grew out of the planting hole. Therefore, one application of sulphur was sufficient and should be confined to planting holes within the demarcated patches.

Post-planting methods

Disease detection : The detection of infected trees periodically by the time consuming collar inspection method was widely adopted in Malaysia (Napper, 1932 a, b ; 1938), until Alston (1950 c) and Fox (1961 a, b) found that wounds caused during collar inspection increased the disease susceptibility. The recognition of infected trees by foliar symptoms is less expensive, fast and can be done more frequently (Newsam, 1964). Further investigations showed that it was not worthwhile to cure infected trees showing foliar symptoms

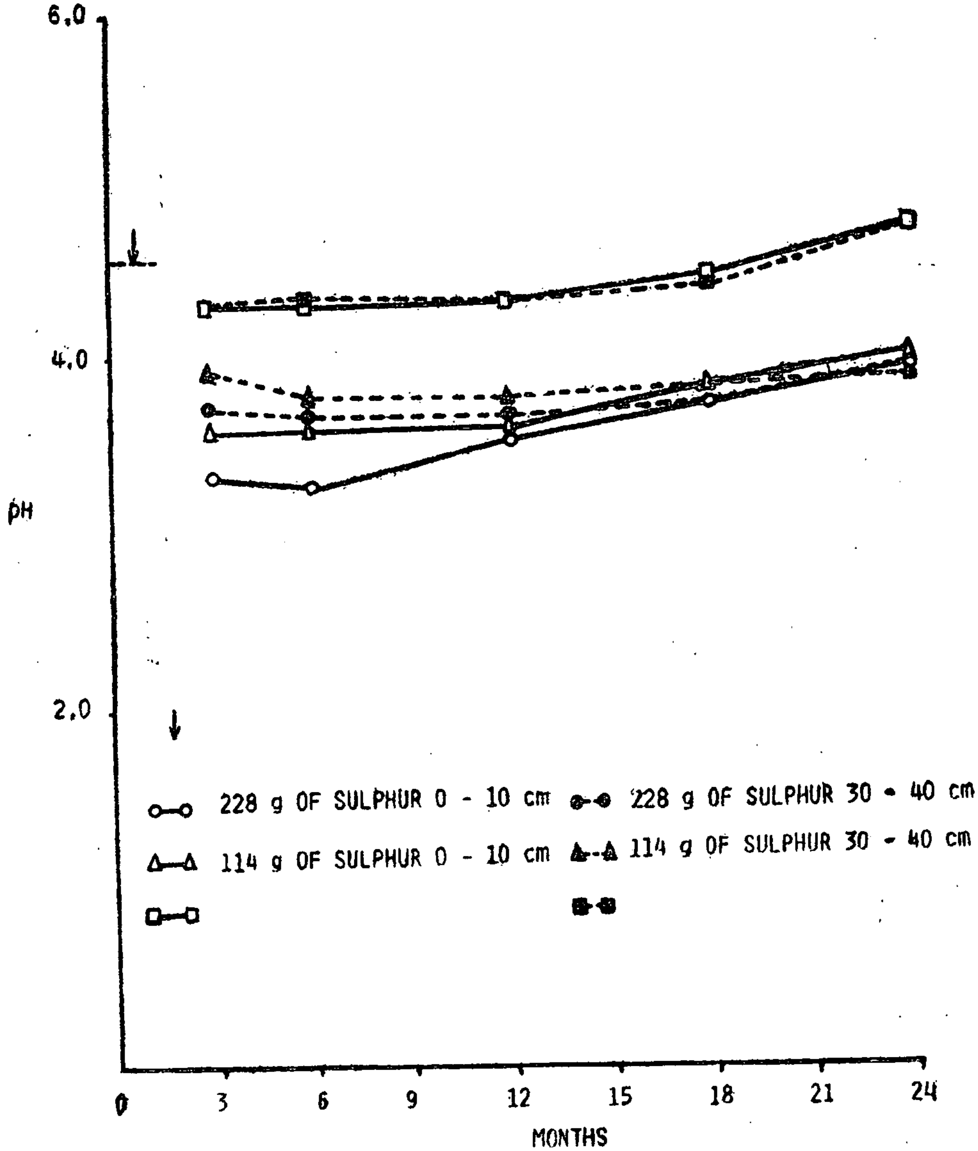


Fig. 3. Change in soil pH after amendment with sulphur.

but they served a useful purpose in indicating foci of infection so that the neighbouring trees could be protected (Fox, 1961 a, b). The use of this method was also recommended in Sri Lanka (Peries, 1970). In Ivory Coast, detection by baiting (Declert, 1964 ; Martin and de Plessix, 1969) was recognised as a cheap, effective and less injurious method of identifying the infected trees. However, Fox (1977) observed that apart from obviating wounding it was less advantageous in that it resulted in misidentification with *R. zonalis* and further, there was no indication of the activity and size of the inoculum in the soil. The use of shrubs to indicate the centres of infection was advocated by Bertrand and Minor (1937) but Newsam (1963) and Fox (1961a) pointed out that its economic disadvantages far outweighted their value as a root disease indicator, as it would perpetuate the infection and transfer it to immature rubber trees.

Treatment of immature trees : The earliest method of treatment of white root disease was to uproot the infected trees (Petch, 1921). Later, Napper (1932 a, b ; 1938) recommended excavation and removal of all infected roots after tracing them. Further, an application of 2 percent solution of copper sulphate was also recommended after scraping the superficial mycelium from healthy roots. As an alternative to copper sulphate, Riggenbach (1958) recommended the use of 1 percent Tillex, an organomercurial fungicide as a soil drench. This method gave disappointing results as a high percentage of treated trees later succumbed to the disease (Young, 1954). Later, Peries, Fernando and Samaraweera (1963, 1965) proved that it was not essential to use fungicides to control white root disease but mere removal of the food bases was sufficient. A grease-based formulation containing 20 % pentachloronitrobenzene was developed to be applied on the collar of trees, adjacent to infected trees to prevent the epiphytic growth of the fungus (Fox, 1965 b, 1966). This method of treatment was very effective and helped to prevent the spread of the fungus along the rows. It later became a standard practice in the procedure to control white root disease in Sri Lanka (Peries, 1970). In Ivory Coast, the manual eradication process was replaced with the use of Calixin (Tridemorph), which gave satisfactory results when used as a soil drench (Tran Van Canh, 1984). In preliminary trials conducted in Sri Lanka, the same fungicide when used as a soil drench, killed the superficial mycelial growth of trees in the early stages of infection (Liyanage, 1984). This method has to be fully evaluated under field conditions before a firm recommendation can be made.

Treatment of mature trees : If the recommendations are properly understood and promptly implemented, the mature clearings should be free of the disease (Fox, 1964 a). However, in Sri Lanka the incidence of WRD increased with age (Liyanage, 1977), mainly due to the failure to detect and control the disease during the early stages of the growth of the rubber plant. In addition, careless disposal of infected boles and roots, especially during the period of clearing land, allowing unprotected stumps, branches and wounds to be exposed to spore colonisation have also led to the increased incidence of WRD in mature stands. Therefore, prompt attention to seal-off the wounds with a suitable wound dressing such as creosote should help to eliminate the risk of spore colonisation.

Usually in this method of control the trees that can be saved are those adjacent to infected trees. In the course of treatment of infected trees in trials conducted by Liyanage, Wettasinghe and Dharmaratne (1977) it was necessary to reduce the canopy weight by cutting some branches prior to treatment. All infected roots were dug out. The remaining healthy roots were served to leave a gap of about 30 cm to prevent the fungus advancing towards the bole of the tree. All the cut ends were protected with tar. Before refilling the soil, a fungicide containing PCNB as the active ingredient was applied round the collar and the upper end of the tap roots and laterals to cover a distance of about 30 cm. In the control treatments, excision of infected roots and scraping the superficial mycelial growth were sufficient to help the plant to recover by producing new roots. Two men can only treat four 12 — 15 year old trees in this manner and would require one litre of the Collar Protectant.

Cutting trenches in mature plantations to check the spread of the disease has met with little success (Anon, 1974), The difficulty in the proper siting of the trenches and inability to maintain them by regular rounds for desilting have been the contributory factors for using this method only as an emergency measure in the control of WRD.

Clonal susceptibility

A technique for screening rootstocks resistant to *R. lignosus* was developed by Liyanage (1978). He showed that LCB 1320 was consistently tolerant to this fungus. Number of other clones showed varying degree of susceptibility with RRIC 36 being highly susceptible to the disease. Absence of absolute resistance is due to the fact that some seeds in the population that were used for screening could have been cross pollinated, although the seeds were collected from the centre of a large plot.

Exploitation of bare patches

Utilization of bare land : A suggestion was made by Liyanage (1977) to utilize the bare patches created by loss of trees due to WRD, by growing annual and perennial crops. One of the draw backs for proper implementation of this scheme is that the vacant patches of various sizes are scattered throughout the estate and protecting any crop grown in them especially at harvest time against thieving was difficult. It was also suggested to plant quick maturing trees such as *Alstonia,* but the main disadvantage in that was the roots of these trees can perpetuate the fungus and could pass it on to immature trees at replanting. As an alternative, establishment of a good cover will help to enhance decay of infected roots left in diseased patches. It would be prudent to sacrifice 3 — 4 rows of trees round each patch after exploiting them to get the maximum amount of latex. This should be done when the patches are small so that only a few trees are uprooted. This hypothesis has not been tested under experimental conditions yet.

DISCUSSION

The demarcation of diseased patches has helped to eliminate much of the sources of infection and to economise on the use of sulphur by confirming its application to the planting holes within patches. Further, post-planting detection of infected trees by foliar symptoms has been made more effective due to careful inspection of plants within patches of the original stand. Infections in the new stand always occur near the border of infected patches, where the carry over of the infective material is in the form of large stumps that are buried in the soil. Also, felling of trees increases the activity of the fungus of infected roots, which results in the increase of the size of the food base by colonising the remaining roots thus increasing the risk of infection in the clearing.

The number of losses in the new stand is low and remains within manageable limits, although the potential foci for infection, in the old stand was very high. Further, results of the survey also revealed that the incidence was low within the first five years after planting. In the process of uprooting most infected laterals are removed as they are confined to the upper layer of the soil, unless they are cut where they join the bole of the tree to facilitate easy removal of trees or decayed due to the disease. Therefore, most of the sources of infection are removed during land preparation. However, stumps bordering infected patches are potential sources of infection in the new stand. Removal of these sources which remain active for 2 — 3 years could help to eliminate the new infections in the clearing. A thorough cleaning up, however, is precluded on economic grounds and practical difficulties. Substantial evidence is present to show that pre-planting eradication of the infected material is adequate. Therefore, these results are in agreement with those in Malaysia (Fox, 1965a, 1977) and which showed that a thorough pre-planting eradication gives only a marginal benefit and is uneconomic.

Poisoning of stumps with 2, 4, 5 — T helped to kill roots quickly and allowed them to be rapidly invaded by saprophytes which have a high competitive ability. Poisoning of stumps could be done in dry rubber growing areas and also in the wet areas provided infection in the old stand is absent. But stump poisoning is not suitable for heavily infected areas as poisoning cannot eliminate the disease from trees already infected. Creosoting the cut surface of stumps has been recommended in Malaysia to prevent colonisation by basidiospores (Lim, 1976) but under conditions prevalent in Sri Lanka none of the untreated stumps was colonized by spores (Liyanage, 1980).

It has also been shown that change of planting distances between replanting cycles help in reducing the incidence of disease in the new clearing. This is possibly due to locating the new planting points away from the sources of infection there by increasing what Fox (1977) called the " grace period ". When roots of new plants come into contact with the old roots most of them have lost their ability to transmit the disease.

Beneficial effects of creeping leguminous cover plants have been reviewed by Fox (1961a, 1965a and 1977). In the present study, no differences were detected between the legumes and naturals in reducing the tree losses due to WRD, possibly because more legumes were present in the natural plots masking the less beneficial effects of grasses. However, the surface soil containing the leaf litter showed an antagonistic effect on rhizomorph production and growth, compared to soils from a clean weeded area. These findings agree with that of Fox (1965a and 1977). Our preliminary study however, indicated that there was no difference in the rate of decay of infected roots when placed beneath several creeping leguminous covers. Some differences in the growth of *R. lignosus* was noted in soils obtained beneath a cover of *Pueraria* grown on different soil types, indicating that some other factors are involved. These aspects require further investigation. Cover plants encourage the spread of the pathogen amongst their roots which helps in reducing the effectiveness of the inoculum. However, when the cover was not kept away from the base of the collar, infection of the collar region resulted in death of plants. Regular weeding to keep the cover away from the trees is essential.

The application of sulphur to soil decreased the acidity and increased the antagonistic mycoflora (Liyanage, 1980). Sulphur was particularly effective when most of the large laterals were removed. Mixing sulphur with the top soil after planting is better than other methods, as it helps to effectively reduce the pH and increase the antagonistic flora in the soil of the planting hole.

The increase in the incidence of WRD indicates that either control measures are neglected or inadequately carried out. The spread of the fungus within the row can be stopped if the collar of trees neighbouring infected trees are treated during the early stages of the immaturity period. Failure to do this results in the easy transmission of the disease due to over lapping of the roots between plants in the row, eventually leading to death of plants and forming large open confluent patches, which are left fallow until the next replanting cycle.

The possibility of using selfed clonal seedlings which are resistant to WRD opens up exciting prospects to control this disease (Liyanage, 1978). However, further work has to be carried out before this can be done in field scale.

SUMMARY OF CURRENT RECOMMENDATIONS

Pre-planting treatments (cultural methods)

1. Do not establish nurseries in patches affected by white root disease in mature clearings.
2. Demarcation of diseased patches to include 3 — 4 rows of infected trees and stumps.
3. Uproot and burn all infected roots and boles as practicable paying special attention to eradicate roots in the first 30 cm depth, around periphery of infected patches.
4. Change the planting distance between replanting cycles, where ever possible. Locate the new planting row inbetween two rows in the old stand.
5. Establish a creeping leguminous cover crop.
6. Keep the leguminous cover away from the base of the tree by circle weeding.

Planting treatment (Biological methods)

1. Amend soil with 114 g of sulphur
   - (i) Limit the application of sulphur to the plants within the demarcated patches, which were known to be heavily infected in the old stand.
   - (ii) Sprinkle sulphur on the surface to cover about one square meter leaving a 15 cm diameter circle round the base of each plant.
   - (iii) Take special care to prevent direct contact of roots with sulphur as it scorches roots.
   - (iv) Mixing sulphur with the soil in the planting hole and sprinkling sulphur on the surface of soil, gave similar results but the latter was cheaper and helps in checking whether or not sulphur was applied.

Post-planting treatments (Chemical methods)

1. Carryout foliar inspections of trees, every 3 months, commencing 6 — 9 months after planting, up to the time of tapping trees.

2. Confine the foliar inspection to the trees in and around the demarcated patches.

3. Uproot the trees showing advanced stages of foliar symptoms as they are beyond treatment. It may be possible to save such trees, if the infection is detected early, but it is not essential.

4. Trace the sources of infection in the planting row and remove them.

5. Inspect the roots of trees on either side of infected trees.

6. Excise infected roots (latex will not exude when pricking with a pen knife) and scrape-off superficial mycelium from healthy roots.

7. Apply a fungicide containing pentachloronitrobenzene (PCNB) as an active ingredient (Collar Protectant or Fomac 2), to cover about 30 cm of the tap and lateral roots after carefully removing the soil adhering to the roots.

8. Collect all infected roots and burn them at the site. Do not introduce infected roots into areas hitherto free of the disease.

9. Refill soil taking care not to incorporate infected roots.

10. Identify treated trees with a distinctive paint band and also indicate the date of treatment.

11. Supply vacancies with polybag plants in the first year, for which establish about 40 plants per hectare, at the time of planting the clearing.

12. To supply vacancies after the 2nd year, as stump buddings raise 40 plants per hectare, in trenches, these should be located in an area which was free of white root disease in the old stand.

13. Reinspect treated trees after two years and retreat them, if necessary.

14. Just before the final thinning and tapping, carryout a tree-to-tree survey to detect trees which are low to show symptoms of the disease.

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DISCUSSION

Q — D. K. WEERASINGHE (TRI) : The clone, LCB 1320 shows resistance to white root disease. why don't you compare chemical constituents of RRIC 100 and LCB 1320, to ascertain the fungitoxic compounds. Would'nt it be better than Calixin.

A — A. de S. LIYANAGE (RRISL) : We are in the process of examining the basis of resistance. It would be possible to do it only if these clones contain inherent inhibitory substances or develop phytoalexin like compounds after infection. However, it would be difficult to say, at this stage, whether these would be better than Calixin.

Q — ANON : What is the effect of low soil pH of 3 — 4 on the growth of rubber plants ?

A — A. de S. LIYANAGE (RRISL) : We have observed that low soil pH caused by the application of sulphur can cause a slight retardation of growth initially compared to control plants, but this effects disappears in about one year.

Q — Anon : The effect of sulphur persists only for one year. Do you recommend continuous application of sulphur in the same area as a prophylactic treatment ?

A — A. de S. Liyanage (RRISL) : Continuous application at the end of the first year could be useful as a prophylactic measure, especially in areas where the infection was heavy in the old stand. In areas where the incidence was mild this too can be eliminated taking into consideration the present cost of sulphur and labour. Experiments on root development have shown that in the second year the lateral roots grow well beyond the area on which sulphur is applied.

Q — Anon : Would you please explain whether *Trichoderma* or *Penicillium* is more antagonistic to *R. lignosus* under field conditions ?

A — A. de S. Liyanage (RRISL) : Quantitative studies to determine whether *Trichoderma* is more antagonistic than *Penicillia* have not been done under field conditions. This is rather difficult to assess as *Trichoderma* population is more on the surface layers and *Penicillia* are more in the deeper layers.

Q — Anon : What are your recommendation for sulphur applications ?

(i) Which kind of sulphur ?
(ii) Periods of application and frequency ?
(iii) Method of application ?
(iv) Quantity per tree ?

A — A. de S. Liyanage (RRISL) :

(i) Elemental sulphur in powder form of 99% purity
(ii) At the time of planting and sometimes a second application at the end of the first year of planting, where the infection had been heavy in the old stand
(iii) Sprinkle sulphur on the surface of soil and gently fork it in. Mixing with soil is not necessary.
(iv) 113 g (¼ lb of sulphur)

DISCUSSION

SESSION V LEAF AND BARK DISEASES

Q — C. Rodrigo, (JEDB I) : You mentioned that the younger rubber tree is more susceptible to bark rot infection. Could you clarify on that as to how is it that the younger rubber tree is more susceptible than more mature trees.

A — A. de S. Liyanage (RRISL) : The virgin bark is highly susceptible to infection compared to the renewed bark. That is why immature trees are more susceptible than mature trees.

Q — Gnanaratnam, (JEDB I) : There is an apprehension or a fear that when cacao is interplanted with rubber there is possibility of the *Phytophthora* fungus affecting rubber, infecting cacao and causing black pod disease or the canker of cacao. Have you come across any positive evidence to justify this fear ? Are the strains of *Phytophthora* different from the one that cause the black pod and one that causes bark rot ?

A — A. de S. Liyanage (RRISL) : Under Sri Lankan conditions the predominant species that affect rubber is *P. meadii* and the only species that affects cacao *P. palmivora*. With detached plants parts of cacao, it was possible to cause infection with a heavy dose of inoculum of the rubber isolate. *P. meadii*. However, when cross inoculations were done under field conditions the infection was restricted.

Q — M. Nicole, Ivory Coast : Do you know if resistant *Hevea* clones become susceptible to some strains of *Microcyclus* and if they are resistant do they show a particular reaction ?

A — Darmono : There are a number of strains of *M. ulei* and clones show differential susceptibility depending on the strain. In some regions like in Bahia FX 25 is susceptible but in Experito Santo it is free of severe infection. It appears that climatic conditions can also affect the disease severity.

Q — P. de A. Gurusinghe : Department of Minor Export Crops, Matale : Has the genetics of the resistant cultivars to South American leaf blight been worked out, at least to some races ?

A — Darmono : The genetic aspects has an effect in the disease susceptibility. For instance FX 710 was originally resistant to races 1, 2 and 3 but now it is susceptible to races 4, 5 and 6. Genetic aspects need more detailed investigations.

Q — My question is, is it due to major gene resistance or polygenic resistance ?

A — May I suggest that we discuss this question later together.

Q — DAHANAYAKE, Mahawela S.P. Ratnapura : Is there any way of preventing bark rot by way of panel dressings ? That is by way of any chemical treatment ?

A — A. de S. LIYANAGE (RRISL) : Yes, you can, if you protect the tapping panels with fungicides when rubber pods are actively producing inoculum during the South West monsoon season. Several effective fungicides are available. Antimucin (0·83%), Brunolinum plantarium (15%), Difolatan (0·8 — 1·6%), Fylomac 90' (1%) and Ridomil (0·2 — 0·4%). Others like Aliette is being tried. Most water soluble fungicides run the risk of getting washed off, during the wet months when the disease is most active. The use of systemic or water repellant fungicide formulations can give better results.

Q — RANJIT BOPEARACHCHI, Chemical Industries, (Colombo) Ltd., : Dr. Liyanage has already answered part of my question. I would require further clarification from Dr. Liyanage. I know from what he said already that *Phytophthora* problems occur mostly during rainy months. Sometime back RRISL did not recommend tapping during wet weather. I would like to know his views regarding chemical control of *Phytophthora* versus tapping during wet weather ?

A — A. de S. LIYANAGE (RRISL) : It is always better to prevent than cure. However, during the wet months the estimated crop cannot be harvested. Tapping is done on any intervening dry period. We have seen from our studies that an injury to the tapping panel can predispose it to infection. provided there is inoculum and therefore the tapping cut remains susceptible up to 72 h after injury. This means that there is a risk of panels getting infected even if one avoids tapping during wet days. This is why we have been looking for fungicides which are systemic or more persistent. We reported on some work that we have carried out on these lines in 1976.

Q — M. NICOLE, Ivory Coast : You suggested that there was a restricted reaction in tolerant trees. Can you be precise on the nature of some of these reactions.

A — A. de S. LIYANAGE (RRISL) : When the artificial inoculation technique was used to determine clonal susceptibility, two distinct types of reactions were observed. The spreading lesions were always brownish in colony but in the lesions formed in tolerant clones were blackish suggesting that some biochemical changes have occurred in these clones.

Q 1 — DE ALWIS, Mahaoya Estate : I would like to know the preference of the skirt-type rain guards as against the gutter-type and which adhesive you used for the polythene rainguard because when we used this about 20 years ago we found that water filtering through after about 4 weeks, and also much infection of bark rot under the skirt.

A — A. de S. LIYANAGE (RRISL) : From the point of view of bark rot control the skirt type of rainguard is preferred as it will prevent the seepage of inoculum into the cut provided it is properly sealed to the tree. The adhesive we used is Shellkote. We had no seepage upto 20 weeks.

Q 2 — There was another problem that of damage by crickets, quite regularly and so that the skirt had to be replaced ever so often.

A — I think this is one of the reasons for abandoning the skirt. In those days crickets were attracted to the skirt. But today it is reckoned as a minor problem.

Q — TRAN VAN CANH, Ivory Coast : We know that *Microcyclus* has many spore forms ; conidia pycnospores and ascospores. What type of spore did you use for testing the clones ?

A — DORMONO : We used leaf disks and inoculation was done with a conidial suspension, which has been standardized. The lesion size was measured after incubating the leaf disks for a known period at low temperature.

Q 2 — You showed inoculation of leaves of rubber with conidia.

A — We did inoculations of clones including, South American clones and some FX clones. There were differences in lesion size between these clones.

Q — TRAN VAN CANH, Ivory Coast : What is the make of the fogging machine, the fungicides used, rates of application, the quantity of the product for one hectare and frequency of application. Is the efficacy of the fungicide affected at very high temperature ?

A — The make of the machine is Leco Model 120 D. We used three fungicides viz. Benlate, Chlorothalonil, Trifornil. At first we used 100 g of active ingredient per hectare with Benlate, but later we used Trifornil ? Volume sprayed was 7 1 for ha. We took uninfected rubber leaves of clones FX 4163 and FX 3864 and hung them on nylon thread in the field. Then we fogged the area, leaves were collected and brought back to the laboratory for inoculation after the smoke disappeared completely.

We have done some experiments on the speed of fogging and the formulation of the fungicide. We monitored the temperature and found that there is a difference between what is shown in the pyrometer and at the point of emission.

Q 2 — If you have an hour of a day for treatment and if the direction of the wind changes one way, what would you do ?

A — We really use this experiment in flat and square land with roads on the 4 sides to take up any variation of the wind.

Q — TRAN VAN CANH, Ivory Coast : What is the method of control of black stripe and abnormal leaf fall now used in Sri Lanka ?

A — A. de S. LIYANAGE (RRISL) : We no longer control abnormal leaf fall caused by *Phytophthora* spp. as the incidence is mild. This is largely due to the lack of routine control of *Oidium* leaf disease. Consequently the pod formation is reduced resulting in lowering the foci of infection. This integrated approach has been unique and has been in practice for the last 20 years or so.

With regard to bark rot control the fungicides we recommend are Antimucin, Brunolinum plantarium, Difolatan, Fylomac and Ridomil. Experiments are in progress to determine the efficacy of Aliette and Sandarfan.

SESSION 9. SOIL MANAGEMENT

MANAGEMENT OF GROUND COVERS FOR OPTIMUM PRODUCTION

By

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ABSTRACT

The increase in efficiency of the appropriate ground covers by proper management and the effect of such practices on the NPK nutrition of Hevea *are discussed.*

Investigations in use of mixed creeping and bush legumes indicate that several species can be grown successfully and that the adverse effect of Stylosanthus guyanensis was seen only in areas with annual rainfall in the region of 3500 mm, possibly due to the absence of competition for moisture. The use of legumes to supply the considerable amounts of nitrogen needed and thus enhance the vigour and performance of Hevea *have been recognised and the beneficial effects of legumes persisted for 4 years during the early mature period. Although compensatory N applied to trees in naturals improved their growth ; but from an economic point of view, legumes give the highest discounted returns.*

Phosphate application to covers led to better tree girths than where the phosphate was applied to the trees, irrespective of the type of cover grown and this beneficial effect persisted for 8 years after the treatments were discontinued. On the other hand, with K, application direct to the rubber tree appears to be as efficient as its application to the ground covers in particular on K deficient soils.

Guide lines offered for practical applications are :

* *Should endeavour to establish a leguminous cover at replanting.*
* *The most appropriate species of legume should be chosen.*
* *Compensatory nitrogen should be applied where legume establishment and maintenance become difficult.*
* *From an economic and agronomic point of view, P and K fertilizers can be applied to the ground covers during the immature period instead of their application direct to the rubber tree.*

INTRODUCTION

The influence of ground covers on early growth of the rubber trees is believed to be mainly the result of moisture and nutritional advantage. However, the effects have been variable and contradictory. This may be attributed largely to variation in soil and climatic factors. This paper discusses the findings on the use of appropriate covers and their management to increase their efficiency under Sri Lankan conditions.

MATERIALS AND METHODS

Details of five experiments on types and nutrition of covers are discussed in relation to growth and yield of *Hevea.*

Experiment 1

Effects of six leguminous cover species viz. *Pueraria phaseoloides*, *Calapagonium muconoides*, *Desmodium ovalifolium*, *Mimosa invisa*, *Centrosema pubscens* and *Stylosanthus gayanesis* (*gracillis*) on growth of clone PB 86 were studied on two sites in 1977 replantings. The control plots in these experiments were in naturals. Site 1 was located in the Kalutara District receiving on annual rainfall of 3125 to 3750 mm and site 2 in the Kurunegala District with an annual rainfall of 2250 and 2500 mm. Soil in sites 1 and 2 had been of the Boralu (laterization) and Parambe (biotite gneiss) type respectively (Silva, 1969). Experimental treatments were assigned in both sites according to randomized block designs and replicated five times in each sites.

Experiment 2

This experiment was started in 1972, on a sandy loam of the Boralu series using clone PB 28/59. The treatments that were studied in a randomized block design replicated four times are : (1) Sown mixed legumes (mainly *Pueraria phaseoloides* and *Desmodium ovalifolium, L*) (2) Selective elimination of non-legume cover constituents from the natural cover (L : S) (3) Non-selective control of natural cover (N: NS) (4) Non-selective control of natural cover with supplementary nitrogen equivalent to thrice the normal recommendation (N : NSn_1) (5) Non-selective control of natural cover with manuring of rubber controlled by leaf analysis to the levels with sown mixed cover legume (N : NSn_2).

Experiment 3

This experiment was started in 1970 on a sandy clay loam of the Agalawatta series using clone RRIM 623. The design was a split plot, with treatments being replicated twice. Legumes (mainly *Mimosa invisa*) and naturals were in the main plots. Four levels of nitrogen (level two corresponds to the normally recommended rate and level four twice the normal recommendation) and four methods of application of phosphate viz, no phosphorus, phosphorus to cover, phosphorus to rubber and phosphorus to cover and rubber, were in the sub-plots (Table 1).

Experiment 4

The influence of potassium application on growth of Clone PB 68 in a 1977 replanting was studied in this experiment on *Boralu series* soil. Three methods of application of potassium at two levels of K were tested in a randomized block design with four replicates. The experimental treatments were ; Nil potassium, potassium to rubber only, potassium of cover only at two levels of K and potassium rubber and cover at two levels of K (Table 1). In all experiments rubber trees received uniform applications of non-experimental fertilizers according to the Rubber Research Institute of Sri Lanka (RRISL) recommendation (Anon, 1980).

Table 1. *Experimental fertilizer schedule*

Period	Experiment 3 Rock, phosphate (28% P_2O_5) (oz./tree) Pr	Pc	Experiment 4 Muriate of Potash (60% K_2O) (oz./tree) Kr	KC-1	KC-2
Year 1	6	2	2	2	4
Year 2	12	2	4	2	4
Year 3	18	2	6	2	4
Year 4	18	1	6	1	2
Year 5	18	1	6	1	2
Year 6	—	—	6	—	—

RESULTS AND DISCUSSION

Types of covers

The effect of various leguminous covers on growth of immature *Hevea* that were assessed in Experiment 1 at two sites by measuring final girth prior to commencement of tapping (Table 2) indicates that in general, growth of trees in legumes was superior to the trees in naturals except *Stylosanthus guyanensis* which continued to show a depressive effect on growth of immature PB 86 in site 2 located in the Kurunegala District, where the annual rainfall is much lower than at site 1.

Table 2. *Effect of ground covers on final girth of immature* Hevea *(PB 86)*[a]

Covers	Boralu (laterization) 3125 — 3750mm	Parambe (biotite gneiss) 2250 — 2500mm
Naturals (control)	48·12	48·63
Pueraria	52·83**	54·40**
Calapogonium	50·58*	52·88**
Desmodium	50·70*	52·25**
Mimosa	49·22	53·63**
Stylosanthus	50·20*	50·04

The differences in performance of rubber under *Stylosanthus* appear to be due to the differences in soil moisture levels between the two sites. Table 3 shows the rates of transpiration as measured by a parometer on leaf samples from rubber and cover plants growing in site 1. Although the period January to April had been fairly dry in 1983 and there had been a steady decline in the rate of transpiration over this period, yet there appears to have been sufficient moisture in the soil. This suggests that in the wet districts *e.g.* Kalutara, competition for moisture between *Stylosanthus* and immature rubber may not exist to the extent of retarding growth of immature rubber in comparison with conditions in districts with low rainfall *i.e.* Kurunegala. Another aspect that emerges from this data is that it would be possible to apply fertilizers during the dry periods of January and February if there had been approximately 1000mm of rain in November/December of the previous year.

[a] In this and all other tables *, ** and *** indicate those treatments differing from the control at $P = 0{\cdot}05, 0{\cdot}01$ and $0{\cdot}001$ respectively.

Table 3. *Rate of transpiration (microgram cm-1 sec-2)*

Sample	January	February	March	April
Rubber	6·588	6·030	3·544	3·464
Pueraria phaseoloides	15·720	11·632	13·452	7·191
Desmodium ovalifolium	5·62	1·38	1·34	1·06

In experiment 2, results at the end of 10 years from planting (Table 4) showed that the trees under legumes were superior to the trees in naturals with regard to both girth and early yield. Other treatments with extra nitrogen to naturals have also shown effects similar to the legume treatment suggesting that in the absence of legumes extra nitrogen will have to be applied, in some cases as high as three times the normal recommendations.

Table 4. *Effects of ground covers on growth and yield of immature* Hevea (*PB 86*) *at the end of 10 years*

Covers	Mean girth (cm)	Yield (kg/ha)
Naturals (control)	56·1	1800
Legumes	61·5*	2506*
Elimination of non-legumes	58·9*	2440*
Naturals with extra N	60·5*	2578*
Naturals with extra N based on leaf analysis	58·8*	2402*

Some beneficial effects of legumes are presented in Table 5. Contributions by cover leaves, green matter, litter and litter C/N ratio, were all in favour of legumes. Other benefits of legumes include total dry matter production and the total N content in leaves per tree. To illustrate this point, few trees were chosen in the experimental area at random, they were completely defoliated and total dry weight and N content were recorded (Table 6). More dry matter production obviously indicates higher physiological activity in the tree and higher total N content in leaves would result in higher nitrogen reserves in the tree. In deciduous trees like rubber it is known that prior to wintering *i.e.* defoliation, nutrients in the leaves move back into the tree (Yogaratnam *et al*, 1976) and are retained in the trees as reserves. This "nutrient bank" within the tree provides the new shoots with nutrients at the time of refoliation.

Table 5. *N. concentrations (%) and C/N ratio, 42 months after planting*

Covers	Cover leaves	Green matter	Litter	Litter C/N
Weeds	1·60	1·03	1·65	22·26
Legumes	2·22***	1·46***	2·26***	12·09***
L; Selective	1·98*	1·14	2·15***	13·38***
N; n_1	1·72	1·01	1·68	18·55
N; n_2	1·64	1·07	1·57	19·18

Table 6. *Total dry weight and N content of leaves per tree (g)*

Covers	Dry wt. of leaves	N content of leaves
Weeds (control)	455	14·78
Legumes	1856***	61·76***
L ; Selective	896*	29·09*
N ; n_1	794*	25·16*
N ; n_2	435	13·40

Nutrition

Phosphate. Due to the restricted movement of phosphate in the soil, phosphate availability from applied fertilizers is rather low. Different methods of application of phosphate indicated that P application direct to ground cover is an efficient method of increasing phosphate uptake by *Hevea* trees (Table 7). P to covers showed higher leaf P values than P direct to rubber at the end of 6 years from planting. This increase in leaf P concentration obviously increased girthing and percentage tappability of trees at the end of 6 years (Table 8).

Table 7. *Effect of phosphate application on P concentration in leaves* (%)

Phosphate	End of 6 years
Nil P	0·254
P to rubber	0·277**
P to cover	0·289***
P to rubber and cover	0·291***

Table 8. *Effect of P application on final girth and percentage tappability* (*6 yrs*)

Treatments	Final girth (cm)	Tappability (%)
Nil P	45·51	28
P to rubber	46·71	39*
P to cover	49·76***	55***
P to rubber + cover	50·14***	57***

The effect of applying phosphate to covers also showed long residual effects on production. Mean girth and yield data at the end of 12 years from planting (Table 9) suggests that the beneficial effect of phosphate applied to covers persisted for a period of approximately 8 years from the time P application was discontinued. Some of the possible reasons for this effect had been discussed by Yogaratnam *et al* (1976).

Table 9. *Effect of Phosphate application on its residual effect at the end of 12 years*

Treatments	Mean girth (cm)	Mean yield (kg/ha)
Nil P	64·28	1418
P to rubber	65·98*	1565*
P to cover	68·33**	1753**
P to rubber + cover	68·24**	1660**

Potassium

With regard to potassium, mobility of K ions in the soil in not a problem, but K application was reported to have increased nitrogen fixation in some legumes.

An experiment similar to the above but with the application of K to legumes indicated (Table 10) that unlike phosphate, the application of K direct to the rubber tree appeared to be as efficient as its application to the ground covers in particular on K deficient soils. Increasing the level of K beyond the current recommendation may not be beneficial.

Table 10. *The effect of potassium application on growth and tappability of PB 86*

Potassium		Mean girth (5 yrs.) cm	Final girth (year 6) cm	Percentage tappability (year 7) (%)
K to rubber :	Nil	39·64	45·01	31
	Level	43·06**	48·85**	52**
K to cover :	Nil	37·04	42·31	29
	Level 1	43·23**	48·95***	54**
	Level 2	43·78**	49·54***	51**

PRACTICAL APPLICATIONS

- Establish leguminous covers at planting.
- In high rainfall areas any legume species is suitable.
- In low rainfall areas *Stylosanthus* should be avoided.
- Some effects of legumes persist for about 4 years during the early mature phase.
- In areas under non-legume covers, application of extra nitrogen is important.
- Application of P to cover is move beneficial than application direct to rubber.
- Residual effects of P applied to immature plantations would persist for about 8 years.
- In K deficient soils, potassium can be applied either to rubber or to covers.

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SOME ASPECTS OF MOISTURE AND SOIL CONSERVATION IN RUBBER PLANTATIONS

By

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SUMMARY

Results of some investigations on soil and plant water status and the effects of leguminous ground covers, mulch and naturals (weeds) in minimising losses of moisture and soil in rubber replantings during the early stages of growth of plants are discussed. Soil water in the root zone was estimated by the neutron moisture meter whilst plant physiological and micro-meteorological measurements were maintained on the above ground portion of the system.

In preliminary investigations, the location of access tubes for the use of neutron probe, a calibration curve for the neutron moisture probe and sampling techniques for measuring of leaf water potential in Hevea *using a Scholander pressure bomb have been finalised. A close relationship appeared to exist between available soil water and rainfall pattern for a 90 cm profile.*

Among the different soil management practices, dead mulch exhibited the highest soil moisture storage capacity in comparison with other practices such as growing leguminous covers or naturals or leaving the land bare (clean weeded). Similar results were observed with regard to other parameters such as leaf water potential, relative water content of leaf and leaf water deficit. Girthing of plants also showed similar effect with plants in mulch growing more vigorously than the plants under other practices. Investigations on the influence of ground covers including mulch on run-off and soil losses indicated that mulching with Guatamala grass loppings can reduce run-off and soil erosion markedly as compared to clean weeded and bare land. Plots in legumes and naturals also showed effective control of run-off and soil erosion losses, the beneficial effect of legumes was seen from the second year.

INTRODUCTION

Rubber plantations in Sri Lanka are generally situated on sloping land with varying degrees of steepness and the intensity of rainfall recorded in these areas had also been variable. The extent of moisture and soil losses by competition, surface runoff and erosion varies widely depending on the type of agro-management practices adopted (Ellison, 1952; Jackson, 1964; Mannering and Meyer, 1963 and Yogaratnam *et al*, 1977).

Numerous factors are involved covering a wide range of biological cultural and climatological parameters that must be known or measured in order to understand the effects of moisture and soil losses on the performance of rubber plants in the field. Among those are soil moisture (Laycock, 1960; Haridas, 1980) leaf water potential (Scholander, 1965) relative water content (Weatherley, 1950) specific leaf weight (Pearce, Carlson, Barnes, Hanson and Hart, 1969) soil erosion (Manipura, 1972) surface runoff (Hudson, 1957; Adams 1966) and loss of nutrients (Lal *et al*, 1980).

This paper discusses the results of some investigations on soil moisture, erosion and surface runoff and the effects of leguminous covers, mulch and naturals (weeds) in minimising losses of moisture and soil in rubber replantings during the early stages of growth of plants.

MATERIALS AND METHODS

In soil-plant-water relation studies the neutron meter is used extensively to monitor soil water in field studies concerning the response of the plant to water content of the soil.

Preliminary Investigations

Calibration of neutron meter: Establishment of the basic calibration curve for the particular neutron meter, type of installation and for the general class of soil in the experimental areas is an important aspect. Field calibrations were therefore made by obtaining moisture meter readings in duplicate at depths of 10 cm intervals from 10 — 160 cm. For gravimetric determination of moisture content and for bulk density determination, soil samples were collected from each depth at which moisture meter readings were recorded by digging pits around each access tube.

Some of the objectives of a measurement programme based on the neutron meter is the estimation of some complex variables of the profile water balance such as run-off and change in the soil water store. This profile water store is the difference between the upper and lower limits of water content at some specified depth, usually the root zone.

Location of access tubes: In order to minimise sampling errors due to location and mode of installation of access tubes in the field, a pilot study was conducted to determine the most suitable position in relation to the rubber plant for the installation of access tubes. Trees were selected at random in a 3 years old replanting and access tubes were installed at distances 60, 120 and 180 cm (2, 4 and 6 ft) from the trunk of each plant in four directions, north, south, east and west, making in all 12 positions. Moisture readings were recorded weekly at depths of 10 cm intervals from 10 to 90 cm, which generally covers the rooting zone of immature rubber plants.

Sampling for leaf water potential (LWP) measurements: Determination of a suitable leaf sampling technique for the measurement of LWP is important in order to minimise variations due to factors such as age (maturity) and position of leaves (effect of light) and the time of the day (differential rates of transpiration). Leaves of 3 stages of maturity, tender, intermediate and mature were collected from two positions ; exposed to sunlight and shaded, at three times of the day ; 0900 to 1000, 1300 to 1400 and 1700 to 1800 hours. LWP measurements were made with a Scholander Pressure Bomb by inserting the leaf with petiole, after making an incision around the petiole and allowing one minute for the latex to ooze out from the leaf.

Experiment 1

This experiment was started in a 1981 replanting and was designed to study the effects of different soil management practices on moisture stress and their influence on growth of immature PB 86 plants. Four ground cover management practices that were studied in a randomized block design with three replicates are ;

(a) Bare (clean weeded)
(b) Mixed legumes (*Pueraria phaseoloides* and *Desmodium ovalifolium*)
(c) Natural cover
(d) Dead mulch

The soil classified as from the 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 (Silva 1964). Soil analysis indicated the following mean values : pH 4·7 CEC 5·9 ; organic C% 1·7 total N 0·14% and total P 5·52 ppm in the planting strips. The water holding capacity of the soil was 40—60% and bulk density was 1·29.

Access tubes were installed in experimental plots and weekly counts for soil water content were made using a neutron meter at depths of 10 cm interval from 10 to 90 cm. Soil samples were collected at 6 monthly intervals for determining some physical and chemical characteristics. (Mechanical analysis by pipette method and bulk density by using core samplers, Organic C by Walkly and Black's method exchangeable K and Mg and CEC by ammonium acetate—pH 7). A Scholander Pressure Bomb was used to assess leaf water potential fortnightly. Relative water content of leaf, leaf water deficit (Weatherley, 1950) and specific leaf weight (Pearce, Carlson, Barnes, Hart and Hanson, 1969) assessments were also made at 3 monthly intervals. Leaf samples were collected at 6 monthly intervals for chemical analysis and girth measurements were recorded at 3 monthly intervals.

Experiment 2

In this experiment the effect of leguminous covers, naturals (weeds) and mulch on runoff and soil erosion losses during the early stages of growth of rubber in replantings were studied using soil erosion and runoff plots. Plots were constructed at slopes of 35 to 40%. Each run off plot (Fig. 1) contained four planting points (PB plants) surrounded by plot bounderies made of brick walls. At the bottom end of the slope, a conveyance channel helped the water to flow through a "H-flume" device into a collection tank via a multislot divisor. The collection tank at the end measured the total volume of water and soil collected.

The experimental treatments consisted of (a) Leguminous covers (mixed growth of *Pueraria phaseoloids* and *Desmodium ovalifolium* (b) Naturals (weeds) (c) Mulch (Guatamala loppings) and (d) Bare (clean weeded).

RESULTS

Preliminary Investigations

Calibration curves

Calibration curves obtained from 29 readings taken over a period of 12 months (Fig. 2) for the surface (0 — 10) is, moisture content ($\Theta = 0{\cdot}41$ Count Ratio (CR) — 0·18 and (Fig. 3) for the sub surface (10 — 160 cm) is $\Theta - 0 = 0{\cdot}52$ CR — 0·39.

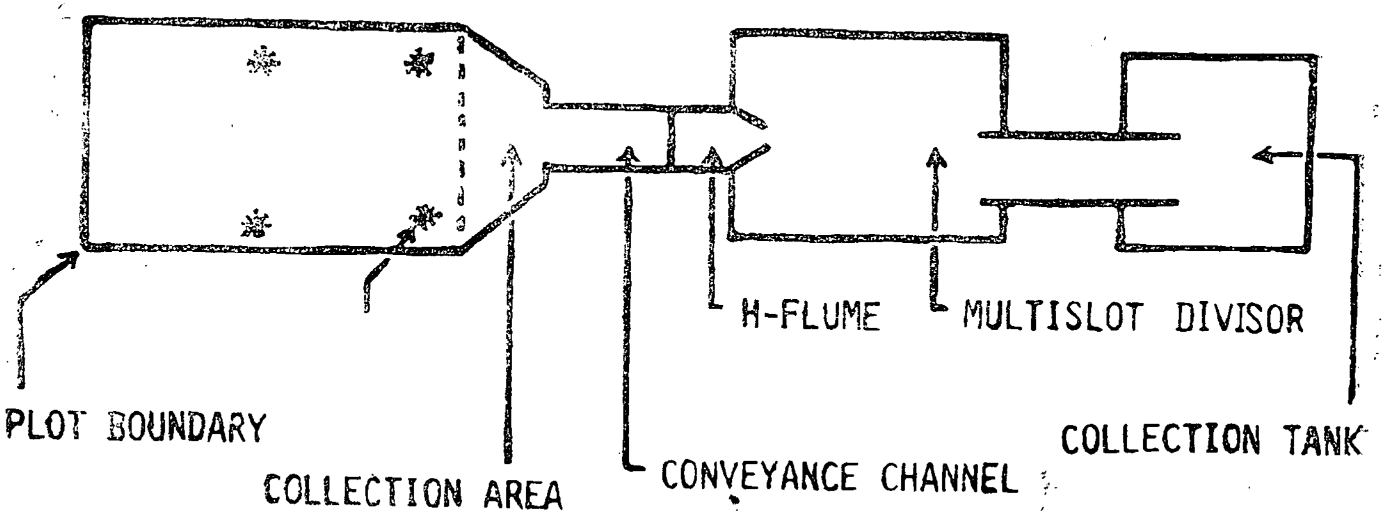

Fig. 1. Soil erosion and run-off plot.

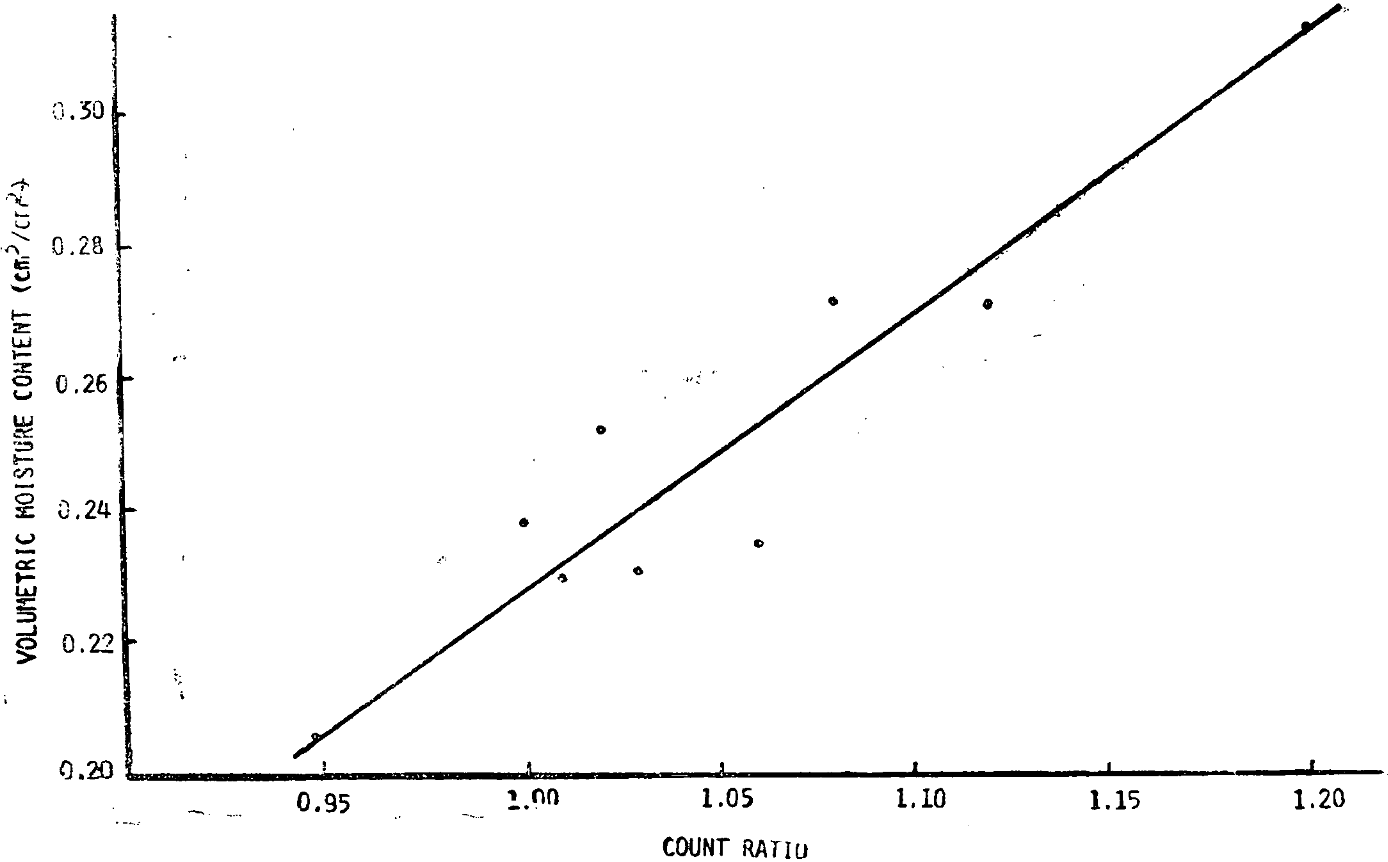

Fig. 2. Field calibration of neutron moisture meter for the surface layer 0-10 cm.

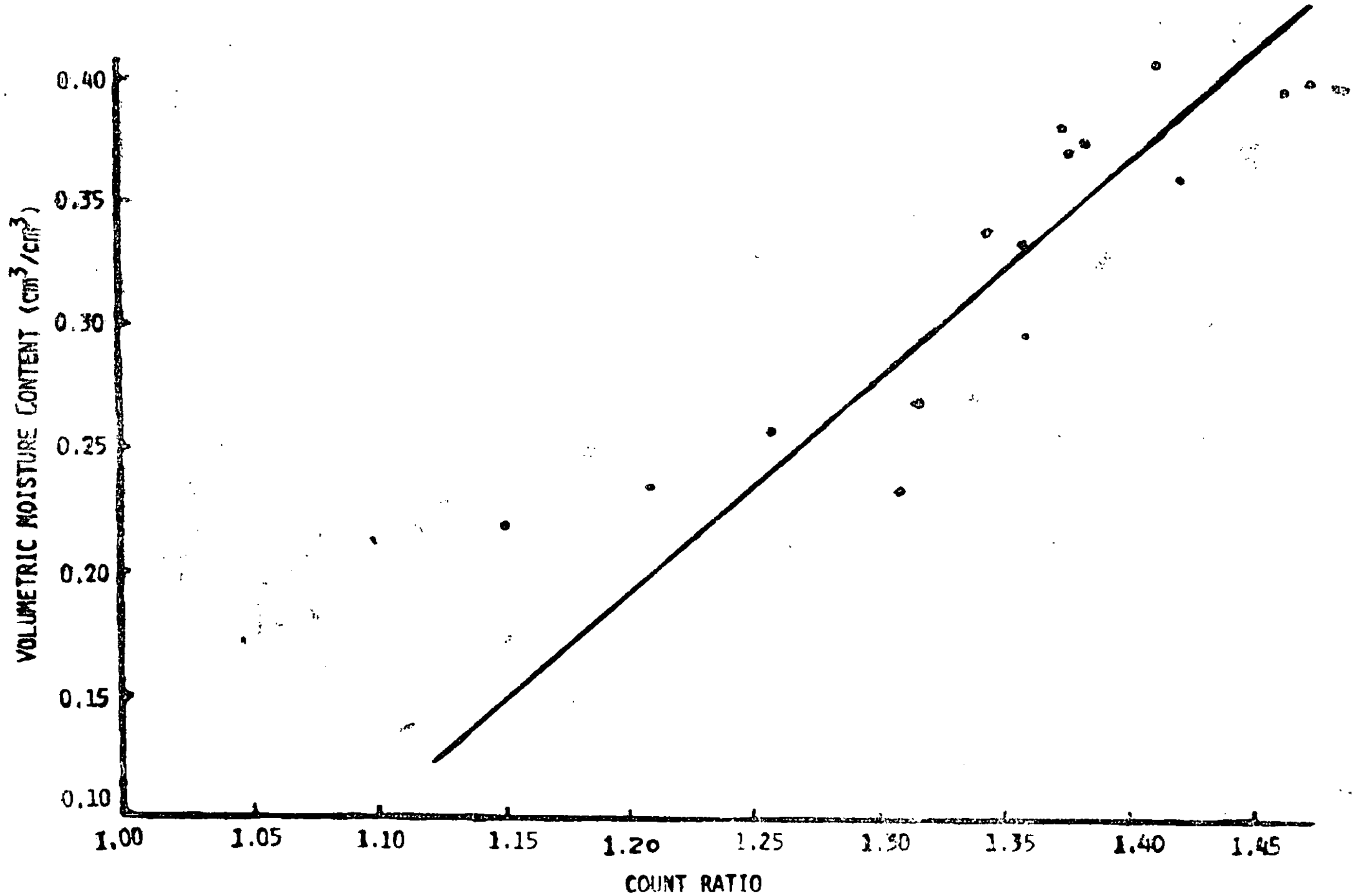

Fig. 3. Field calibration of neutron moisture meter for the sub-surface layer, 10—160 cm.

Location of access tubes

Statistical calculations (co-efficient of variation) of count ratios obtained from 12 positions of access tubes in relation to planting points over a period of 12 months from September 1982 indicate that during wet period the count ratio may not be influenced by the location of the access tubes. But on dry days in general, distances 1·2 m to 1·8 m (4 to 6 ft.) from the tree would appear to give the most reliable information with increasing accuracy at lower depths. No significant difference was seen in relation to the direction of the location of access tubes (Table 1).

Table 1. *Co-efficient of variation (%) different at depths and distances of access tubes*

Depth (cm)	Distance (cm) 120	180
10	30·6	28·6
20	66·4	56·3
30	49·2	45·3
40	40·7	33·1
90	12·1	15·3

Soil moisture status

Fig. 4 illustrates the available water storage capacity (AWSC) of the experimental area over a period of 12 months, which has an upper limit of 235·5 mm (field capacity) and a lower limit of 131·3 mm thus yielding an AWSC of 104·2 mm. Fig. 5 illustrates the available soil water in relation to the total rainfall for a 90 cm profile, which is generally the rooting depth of immature rubber, over a period of 12 months. A clear relationship appears to exist between available soil water and total rainfall during this period.

Leaf water potential

A study on the leaf sampling technique for the assessment of LWP indicated that sampling between 1300h to 1400h was the most suitable time for LWP measurements. It also appears that sampling of exposed leaves in the intermediate and mature stage is likely to give the most consistent results (Table 2).

Table 2. *Co-efficient of variation (%) of factors influencing leaf water potential*

Position of leaves	Time (h) 0900 to 1000	1300 to 1400	1700 to 1800
Shaded, mature	7·5	9·8	19·0
Shaded, intermediate	7·5	5·2	19·8
Shaded, tender	10·5	7·6	17·2
Exposed, mature	10·5	4·1	13·8
Exposed, intermediate	9·8	4·6	14·0
Exposed, tender	15·5	10·6	12·5

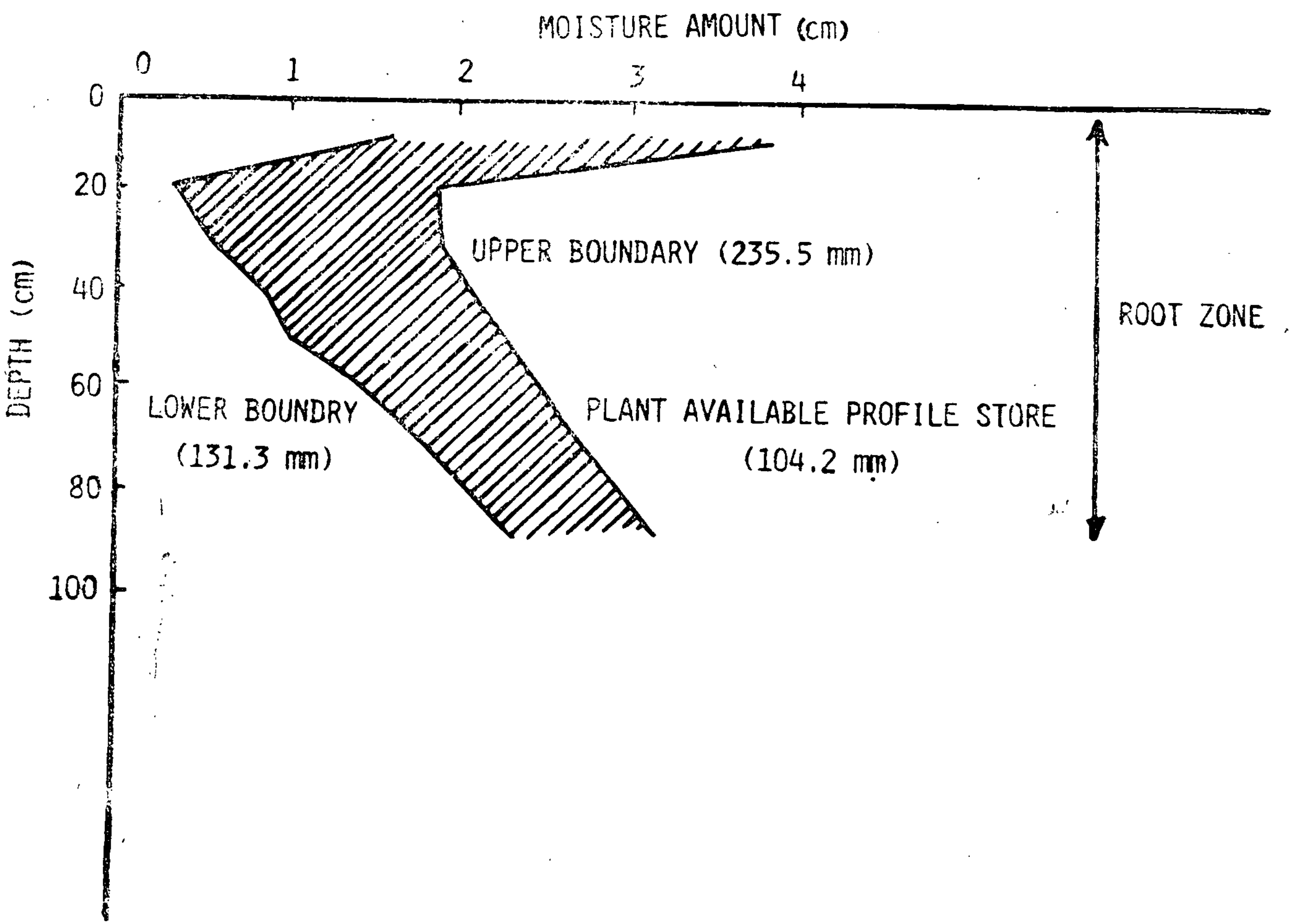

Fig. 4. The available water storage capacity (AWSC).

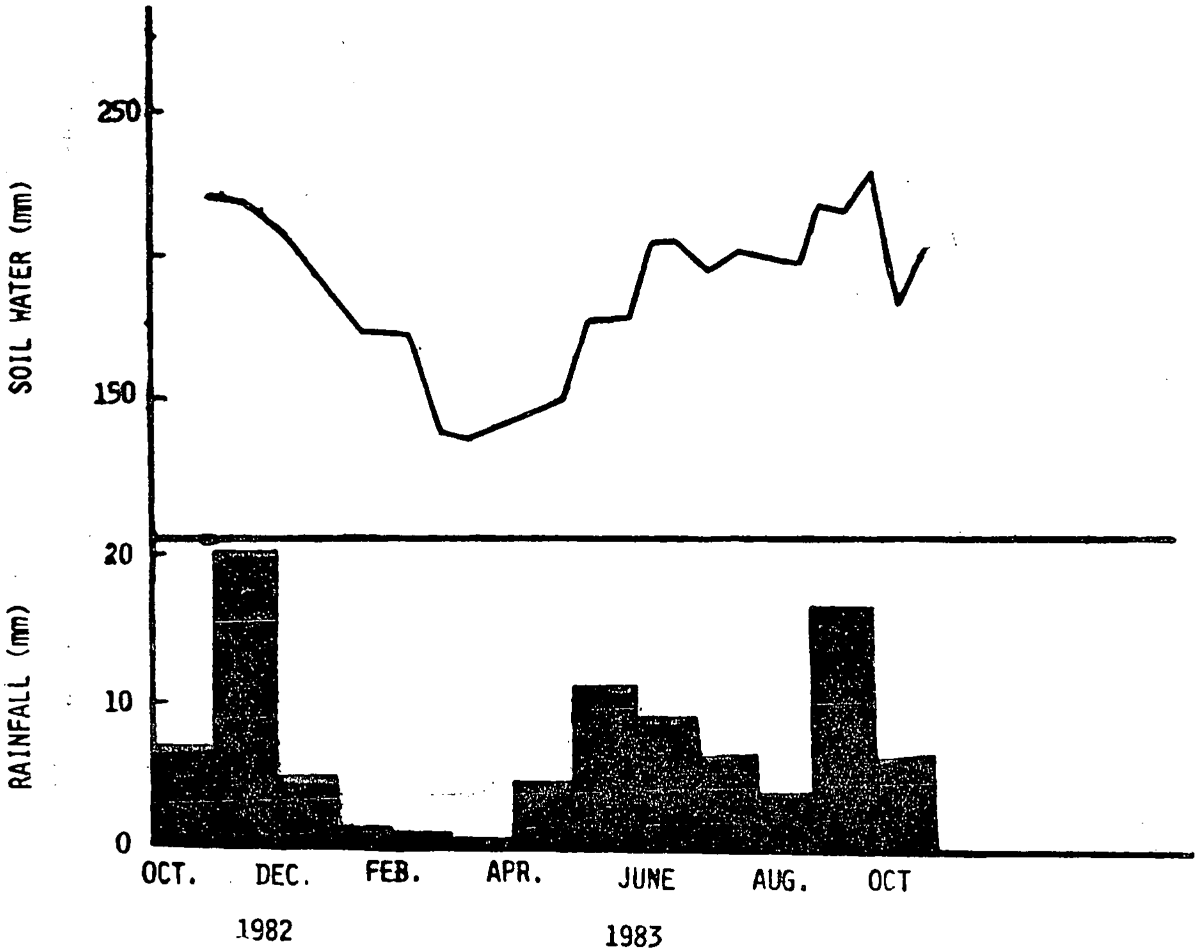

Fig. 5. Available soil water in relation to rainfall

Experiment 1

Among the different soil management practices that were tested for their effects on moisture conservation in immature rubber plantations, plots in dead mulch exhibited the highest soil moisture storage capacity of 27·64 cm in comparison with other practices such as growing leguminous covers or naturals or leaving the land bare (clean weeded) (Table 3). Similar results were observed with regard to other parameters such as LWP (Table 4) relative water content of leaf (Table 5) and leaf water deficit (Table 6). Girthing of plants (Table 7) also showed similar effects with plants in mulch growing more vigorously with a girth of 19·49 cm at the end of 24 months as compared to a value of 17·25 cm in the plots in naturals. The cation exchange capacity of the soil was also increased by mulching (Table 8).

Table 3. *Effect of different soil management practices on soil moisture storage capacity*

Treatment	Soil moisture storage capacity (cm)
Bare (clean weeded)	18·3
Naturals	24·3
Legumes	21·7
Dead mulch	27·6

Table 4. *Effect of different soil management practices on leaf water potential of rubber (LWP)*

Treatment	LWP (bars)
Bare (clean weeded)	26·7
Naturals	26·5
Legumes	27·4
Dead mulch	22·1

Table 5. *Effect of different soil management practices on relative water content of leaves (RWC)*

Treatment	RWC
Bare (clean weeded)	0·814
Naturals	0·849
Legumes	0·820
Dead mulch	0·867

Table 6. *Effect of different soil management practices on leaf water deficit in rubber (LWD)*

Treatment	LWD (%)
Bare (clean weeded)	18·6
Naturals	15·1
Legumes	18·1
Dead mulch	13·3

Table 7. *Effect of different soil management practices on the girth (cm) of rubber trees*

Treatment	March 1983	June 1983	Dec. 1983	June 1984
Bare (clean weeded)	10·7	12·2	16·4	20·1
Naturals	10·2	11·9	15·3	18·6
Legumes	10·7	12·5	15·9	18·9
Dead mulch	11·1	12·1	17·1	21·5

Table 8. *Effect of different soil management practices on CEC and organic carbon of the soil*

Treatment	CEC (meq/100g)	Organic carbon (%)
Bare (clean weeded)	3·3	0·9
Naturals	3·9	1·4
Legumes	5·3	1·3
Dead Mulch	5·5	1·4

Experiment 2

Data on the influence of ground covers including mulch on soil erosion losses (Fig. 6) indicated that the plots in Guatamala grass loppings had the least soil erosion loss as compared to other treatments. Plots in bare land recorded a total soil loss of 60·91 tons/ha over the 3 year period in comparison with a loss of only 3·55 tons/ha in the plots in mulch. In general, the plots in legumes and naturals also showed effective control of soil erosion loss. The beneficial effect of legumes was however seen from the second year only. Similar results (Table 9) were obtained with regard to run off losses as well as with the maximum runoff values in the bare plots *ie* plots that were clean weeded. In terms of nutrients all these amount to a loss of approximately 0·027 and 0·003 tonnes of N and K respectively (Table 10).

Table 9. *Effect of different soil management practices on total volume of water (litres) collected during the 3 years period*

Treatment	Year 1	2	3
Bare (clean weeded)	3701	2805	481
Naturals	1973	1259	124
Legumes	4492	2163	66
Dead mulch	2468	2089	277

Table 10. *Effect of different soil management practices on loss of nutrients (tonnes/ha) from soil (mean of 3 years)*

Treatment	N	K
Bare (clean weeded)	0·027	0·003
Naturals	0·001	0·0001
Legumes	0·009	0·001
Dead mulch	0·002	0·0002

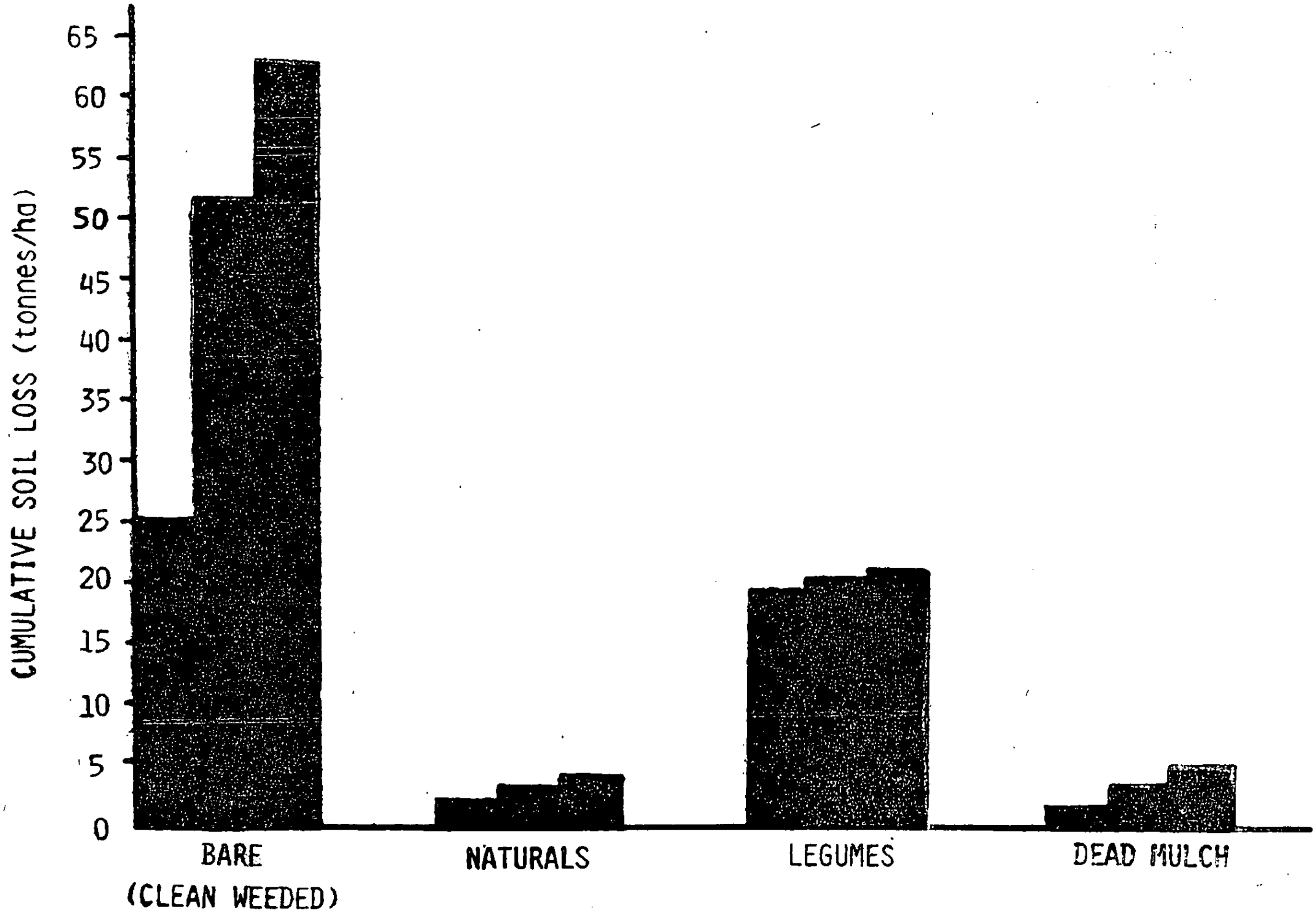

Fig. 6. Effect of ground cover treatments on total soil loss.

DISCUSSION

In studies on soil-plant-water relations the Neutron Meter is used extensively to monitor soil water balance in the root zone whilst plant physiological and micrometeorological measurements are maintained on the above ground parts of the system. This study clearly establishes the effectiveness of these measurements in immature *Hevea* plantations. It had been possible to establish fairly reliable calibration curves for the neutron probe for the surface, 0 — 10 cm, and subsurface soils 10 — 160 cm, possibly due to the absence of soil horizons with contrasting physical properties within the experimental area. This calibration would in any case be sufficient for comparison of agronomic treatment effects within the experimental site.

It appears that during dry periods, distances varying from 1·2 to 1·8 m from the trunk of the tree are suitable for assessing the water content of the soil profile. This is in line with the previous reports based on the use of radiotracers that root activity in immature plantatinos is more towards the tree trunk than away from it (Liu Chong-Qun, 1984). In our study, it is possible that on wet days when the soil was saturated with water, daily changes due to transpiration losses may not have caused much fluctuation in the soil water content. But on dry days, the process of depletion and recharging from the moist layers may be continuous in the profile close to the trunk. An incidental but important observation that emerges from this is that fertilizer applications to immature rubber should be confined to areas approximately 60 cm from the base of the tree for efficient uptake.

The available soil water storage capacity of 104·2 mm with the upper and lower limits of 235·5 and 131·3 mm, respectively, is likely to be the amount of water that was available to the plants, both rubber and covers over a period of 12 months in 1982. Clearly these upper and lower limits are somewhat arbitrary, yet in practical terms it has been possible to obtain a useful estimate of the profile water store and the available water storage capacity for Boralu type soils receiving a total rainfall of 2·80 mm. This is further elaborated by the data on available soil water in relation to precipitation where a clear relationship exists between these two variables. It is evident that even during the most dry periods in 1983 *ie* in January, February and March the available soil water has been in the region of 140 to 175 mm, with the lowest value of 140 mm in February. Total precipitation in the preceding 3 months *ie* in October, November and December 1982 had been around 1000 mm. It therefore seems possible to apply fertilizers, at least to mature areas even during the dry periods of January to April if there had been approximately 1000 mm of rain during the north east monsoon in the previous year.

However, it is known that during periods of water stress, growth of immature plants may be retarded to the extent of delaying the immaturity by even over 12 months (Sivanadyan, Hadrias and Pushparajah, 1973, Pushparajah and Haridas, 1976). It appears possible to eliminate or at least minimise the adverse effects of moisture stress by mulching. Soil moisture storage capacity in plots that were mulched was much higher than in the other plots. Moreover, some plant physiological measurements made, for example leaf water potential, relative water content and leaf water deficit, all indicate that the water status of plants were improved in plots that were in mulch in comparison with the plants in naturals or bare or in legumes. Whether it is legumes or naturals they are equally deterimental in effecting evapotranspiration losses. However mulching and legume treatments improved some important soil characteristics for example the cation exchange capacity.

Mulching had been found to be very effective in not only avoiding evapotranspiration losses, but also in preventing run-off and soil erosion losses. Marked reduction in run-off losses with mulching indicates that the soils have inherently high infiltration capacity. Moreover, the surface soils in the mulch, legumes and natural plots were in a more friable condition than the bare plots, which possibly helped in greater absorption of water.

Soil losses that occurred due to erosion from bare lands which were in the region of 61·9 tons/ha could be easily reduced to 3·6 tons/ha by mulching. This would also help in reducing nutrient losses considerably. It is also pertinent to note that soil loss during the first year from plots in naturals is less than that from clean weeded and legume plots, thus emphasizing the need for selective weeding during the early stages of the planting. Any cover treatment other than mulching, takes 6 to 12 months before providing sufficient protection to the soil and therefore substantial soil loss occurs during the first year. It may, therefore, be necessary to mulch the soil immediately after planting and then establish a cover crop or practise selective weeding which would help reduce run-off and soil erosion losses considerably. The importance of legumes in the nitrogen nutrition of *Hevea* has been amply demonstrated by other workers (Mainstone, 1969, Pushparajah and Chellapah, 1969; Yogaratnam *et al*, 1977).

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APPROACHES TOWARDS LAND EVALUATION SYSTEMS FOR *HEVEA BRASILIENSIS* CULTIVATION IN PENINSULAR MALAYSIA

By

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ABSTRACT

In the early stages of development in the country, allocation of land for various uses had been on a laissez faire system. No problems on land use occurred then because land was plentiful. However, with the tempo of agricultural activity increasing rapidly in the past three decades, scarcity of good land and conflicting interests arising from competition for prime agricultural land between perennial crops have led to the need to evaluate land according to its intrinsic qualities and merits. This has resulted in the development of various approaches on land evaluation systems.

For rubber, the first system proposed was the Soil Suitability Classification System in 1972; the classification of which was based on the number and types of soil limitations. The system was non-parametric in approach.

Later systems developed were of a parametric nature; the first being the Soil Suitability Technical Grouping System for Hevea, *proposed in 1975 and was based on an approach whereby scores were accorded to the evaluation of the diagnostic criteria used.*

In 1982, a system to evaluate suitability for rubber cultivation has been developed based on the multiplicative approach. It differs from the other systems by considering the evaluation of climate in addition to the evaluation of the land units.

All three systems developed have been shown to have agronomic logic; higher yields being obtained on the better soils. The paper attempts to account the characteristic features of these approaches and recommends, on the basis of current evidence, a land suitability system for rubber cultivation. To facilitate use of this system, modern soil classification systems e.g. the USDA Soil Taxonomy have been used to describe the local soil units so that this technology can be transferred at a global level.

PREAMBLE AND INTRODUCTION

In the early years of active *Hevea* planting in the East, planters were in the habit of selecting, wherever possible, the banks of rivers or areas liable to flooding for the cultivation of the rubber trees (W. Wright, 1912). This was due to erroneous advice originally obtained from Brazil and traced to the custom of native collectors to tap areas nearest the rivers.

The true forests of *Hevea* were on the highlands and those scattered along the river sides did not reflect the actual conditions under which rubber could be grown. In fact, in the natural habitat, *Hevea brasiliensis* was found mainly on drained sites and occasionally in sites subjected to brief or slight inundations. One species, *Hevea spruceana*, occurred on the muddy soils of the islands and river banks which were subjected to periodic heavy inundation while another species, *Hevea comporum*, occurred in the dry savannah land.

Hevea brasiliensis was introduced into Malaya in 1877, but it was not until the turn of the century that rubber was planted on a large scale (Wycherly, 1963). Choice of land for rubber cultivation then was determined essentially by road accessibility and ease of working conditions. Initially, therefore, the choice of land was restricted to the zone bordered by the steep hills of the Main Range in the interior and by mangrove, peat or padi areas on the coastal areas. Because of difficult terrain, plantings in the early part of this century for rubber hardly exceeded the 225 m (750 ft.) contour (Wycherly, 1963).

The land use pattern for rubber has, therefore, been laid down on the easier terrain following somewhat, the rail and road network systems of the country. Following this, and with the encouraging steady rubber prices, rubber cultivation mushroomed over the country and was grown on a wider range of soils.

The advent of soil survey in Peninsular Malaysia began in the early 1900's. The experiences and contributions from information gathered by soil surveyors culminated in a first schematic classification system of Peninsular Malaysian soils as suggested by Owen (1951), whereby it became evident to land users that soil was a heterogenous unit and land use needs to consider soil properties and quality.

Experience with fertiliser use in rubber culture in Peninsular Malaysia which dates back to 1903 as reviewed by Pushparajah (1977), has shown that response to fertilisers can vary according to soils ; higher responses being obtained on some soils when compared to others. This further reflected on the variable fertility of the different soils.

Recognising, therefore, the heterogeneous nature of soils as reflected by the differing agro-management responses experienced on them, the need to evaluate soil and land units according to their intrinsic qualities and merits gathered momentum in the past two decades. Additionally, the rapidly increasing tempo of agricultural activity in the country, the scarcity of good land and the conflicting interests arising from competition for prime agricultural land between perennial crops emphasised further the importance of this conceptual development on land use. This has resulted in the development of various approaches on land evaluations systems and the purpose of this paper is to account the characteristic features of these approaches. The merits and demerits of the each approach is discussed and suitable land evaluation systems which can be used for rubber cultivation are described.

Soil suitability classification systems for rubber cultivation

Early attempts

A soil suitability classification system for rubber cultivation has been proposed by Chan and Pushparajah in 1972. It is made up of a framework of soil and physiographic features which are considered to be desirable for optimal growth of rubber.

On the other hand, the poorer soils have properties which limit the optimal growth and performance of rubber and these limitations are graded as minor, serious or very serious in their degree of limiting crop performance.

The criteria considered in the classification system are as follows :

Desirable physical properties :

Soil depth up to 100 cm, free of pan/rock outcrop hindrance

Well drained

Good soil aeration

Good soil structure (strong, moderately strong and moderate medium and fine subangular blocky structure)

Friable to firm consistency

Good water-holding capacity

No peat or acid peat deeper than 20 cm

Soil texture with sufficient clay (preferably a minimum amount of 35% clay to retain sufficient moisture and nutrients and about 30% sand to allow for expression of good physical soil properties like aeration and drainage).

Desirable environmental and physiographic features :

Gently sloping or rolling terrain between 2 – 9° slopes (4 – 20%), with minimal soil erosion and surface run-off

Water-table should be deeper than 100 cm.

Desirable chemical properties :

At least medium levels of total nutrient contents of nitrogen (N), phosphorus (P) potassium (K), and magnesium (Mg) with no deficiency of trace elements

A pH of around 4·5

Absence of saline/acid sulphate conditions.

Limitations are properties which limit good crop performance and can be graded as minor, serious and very serious in accordance to its degree of severity on affecting crop performance.

Minor limitations :

Weak soil structure within 90 cm

Moderate drainage conditions

Massive thick hard-pan below 50 cm from the surface or loosely packed gravels within 50 cm from the surface

Less than 50% rock outcrop in a unit area

Susceptibility of soil erosion

Sub-optimal soil nutrient status, reflected by low contents of nitrogen, phosphorus, potassium and magnesium.

Serious limitations :

Slopes steeper than 9° (20%) but less than 16° (36%)

Massive thick hard-pan between 20 and 50 cm of the surface

Between 50% and 75% of rock outcrop in a unit area

Permanent water-table between 20 and 50 cm of the surface

Strong compaction influencing permeability and infiltration

Poor structure (too sandy resulting in no structure or massive due to heavy clay in waterlogged conditions)

Susceptible to moisture stress as reflected by textural and structural qualities

Poor nutrient status.

Very serious limitations :

Slopes steeper than 16° (36%)

Massive thick hard-pan at or very close (within 20 cm) to the surface

More than 75% of rock outcrop in a unit area

Permanent water-table at or near (within 20 cm) the surface

Acid peat layer thicker than 20 cm at or near the surface

Land disturbed by mining activities (tin tailings) and very sandy deposits, with more than 90% sand

Very poor nutrient status.

The consideration of these criteria allows the classification of the soils into the following soil suitability classes.

Class I—The soils in this class have no limitations to rubber cultivation

Class II—The soils in this class have one or more minor limitations to rubber cultivation

Class III—The soils in this class have at least one serious limitation to rubber cultivation

Class IV—The soils in this class have more than one serious limitation to rubber cultivation

Class V—The soils in this class have at least one very serious limitation to rubber cultivation

Later attempts based on parametric approaches

The first indication of a parametric approach towards the evaluation of Peninsular Malaysian soils for rubber cultivation was attempted by Chan *et al* in 1975. This system consists of assessment based on the evaluation of sixteen criteria, namely rock outcrop, effective soil depth, soil texture, wet consistency of the soil, moist consistency of the soil, soil structure, internal soil drainage, presence of peat, acid sulphate status, available water, permeability, erodibility, soil pH, terrain (slope %), susceptibility to flooding and stagnation of water at the surface (Table 1).

Class limits are given for each criterion for the desirable range : minor, serious and very serious limitations. A score of 5 points is given to the desirable range ; 4 points to the range of minor limitation ; 2 points to the range of serious limitation ; and 1 point to the range of very serious limitation.

The total scores are obtained by summation and the maximum score is 80 points (100%). In this Soil Suitability Technical Grouping System for Rubber, the following technical groups are proposed :

Ia 96 — 100%, Ib 91 — 95%
IIa 86 — 90% IIb 81 — 85%
III 76 — 80%
IVa 71 — 75%, IVb 66 — 70%
Va 61 — 65%, Vb 56 — 60%, Vc 51 — 55%, and Vd less than 50%.

The technical groups I to V, are defined in the same manner as the soil suitability classes of Chan and Pushparajah (1972).

Parametric approaches for international application

While earlier systems of soil suitability assessments were confined to evaluation within the country, more recent approaches were aimed for international use. As such, more recent approaches used systems that enabled international correlation. For this, the guidelines of the FAO Framework for Land-evaluation (FAO, 1976) were used.

Table 1. *Principal criteria in grading of soil suitability classes for rubber (after Chan et al, 1975)*

Soil properties / Degree in severity of limitation	Desirable range[5]*	Minor limitation[4]*	Serious limitation[2]*	Very serious limitation[1]*
1. Physical properties rock outcrop (%)	Absence	< 50	> 50 — 75	> 75
Effective depth (a)	> 100 cm	> 60 — 100 cm	> 25 — 60	> 25 cm
Texture	Almost proportionate amounts of sand and silt + clay	(i) Sandy loam (> 50—70% sand) (ii) Clayey (> 50—70% clay) (iii Silty clayey (> 50—70% silt + clay)	(i) Very sandy (> 70 — 90% sand) (ii) Very clayey (> 70—90% clay) (iii) Very silty clayey (> 70 — 90% silt + clay)	(i) Extremely sandy (> 90% sand) (ii) Extremely clayey (> 90% cley) (iii) Extremely silty clay (> 90% silt + clay)
Consistency dry	Soft	Slightly hard	Hard Loose	Very hard
Consistency moist	Friable — Very Friable	Firm	Very firm, Loose	Extremely firm
Consistency wet (a) Stickiness (b) Plasticity	Slightly sticky Slightly plastic	Sticky Non-sticky Non plastic Plastic	Very sticky Very plastic	Extremely sticky extremely plastic
Structure Prismatic Columner	Weak moderate fine very fine	(1) Moderate strong medium (2) Weak coarse	Strong Coarse	Strong very coarse
Angular blocky	(1) Moderate strong fine very fine (2) Moderate strong medium	Weak coarse (for texture coarser than clay loam)	Strong Coarse	Strong very coarse Weak coarse (finer than clay loam)
Internal drainage (b)	Class D well drainage	Class C Moderate well drained	Class B Imperfectly drained Class E Somewhat excessively drained	Class A Poorly drained Class F Excessively drained
Peaty characteristic	Absence of peat	Acid peat > 50 cm from surface: > 25 cm thick peat	Acid peat 25 cm to 50 cm from surface : 25 > 50 cm thick peat	Acid peat layer <25 cm from surface : < 50—100 cm thick peat
Acid sulphate characteristic	Absence of acid	Acid SO_4 layer > 50 cm from surface : > 25 cm thick	Acid SO_4 layer 25 cm - 50 cm from surface ; > 25—50 cm thick	Acid SO_4 layer > 25 cm from surface; > 25—100 cm thick
Moisture retention (based on available water in cm/m)	> 150 cm	> 100 — 150 cm	> 50—100 cm	> 50 cm
Permeability(b)	Moderate	Moderately slow or moderately rapid	Slow or rapid	Very slow or very rapid
Erodibility(b)	Class 1 (slightly eroded)	Class 2 (Moderately eroded)	Class 3 (Severely eroded)	Class 4 (Very severely eroded)
II. Chemical properties pH	Mean 4, 5 range 4·3—4·6	> 4·6 — 5·0	> 5·0—6·0	> 6·0
III. Physiographic features Terrain (c)	0 — 8°	> 8 — 15°	> 15—33°	> 33°
Susceptibility to flooding	No flooding	Floods after very heavy downpours	Flodded after heavy downpours	Floods after light downpours
Stagnation of water at surface	No stagnation	Water stagnates for a few hours	Water stagnates for 3 days	Water stagnates for > 3 days

* denotes point scores given

(a) considers depth to hard pan (limestone, laterite layers, quartz vein, compact parent material, etc.) or to permanent water table

(b) based on the definitions of U.S.D.A. 1960

(c) refers to more commonly occurring slopes only.

Recognising that climate forms the first major part of any land evaluation exercise, a method to assess the suitability of climate has been proposed (Yew and Sys, 1984) and shown in Table 2. The evaluation of climate should be used in combination with the evaluation of the soils and landscape features (Table 3).

Table 2. *Climatic requirements for* Hevea *cultivation**

	Degree of limitation				
Climatic characteristics	0	1	2	3	4
Mean temperature (°C)	28 — 25	24 — 22 29 — 30	21 — 20 31 — 32	19 — 18 33 — 34	< 18 > 34
Mean daily maximum temp.	34 — 29	28 — 27 > 34	26 — 24	23 — 24	< 22
Mean daily minimum temp. (°C)	> 20	20 — 19	18 — 17	16 — 15	< 15
Mean annual rainfall (mm)	> 2000	2000 — 1750	1749 — 1500	1499 — 1250	< 1250
Expected total rain interference (days/yr)	0 — 30	31 — 60	61 — 90	> 90	
Sunshine (hours/yr)	2100	2100 — 1800	1799 — 1400	1399 — 1000	> 1000
Mean annual R.H. (%)	< 80	80 — 100			
Length of dry season (months/yr)	0 — 1	2 — 3	4	5 — 6	6 >

*After Yew and Sys (1984)

The evaluation of both climate as well as soils and landscape follows a parametric-limitation approach whereby scores, ranging from 0—100, are accorded to the diagnostic criteria ; and land indices are obtained by a multiplication process, according to the method of Sys (1978).

Land suitability is categorised into orders, classes, subclasses and units. Two orders are recognised, being suitable (S) for rubber cultivation and not suitable (N). The subdivisions are as follows :

Order S : suitable. Land units with no, slight or moderate limitations and no more than two severe limitations which, do not exclude the use of the land. The land index is more than 25.

Class S1 : highly suitable. Land units with no or only slight limitations which, in combination, give land index values ranging from 75—100.

Class S2 : moderately suitable. Land units with slight or moderate limitations which, in combination, give land index values ranging from 50 to 74.

Class S3 : marginally suitable. Land units with moderate limitations or normally not more than two severe limitations which, in combination, give land index values ranging from 25 to 49.

Order N : not suitable. Land units with more than two severe limitations or with at least one very severe limitation which exclude the use of the land. The land index is normally 24 or less.

Table 3. *Landscape and soil requirements for rubber**

Land characteristics	Degree of limitations 0	1	2	3	4
TOPOGRAPHY (t)					
Slope %	Flat to undulating 0—10	Rolling 11—20	Hilly 20—30	Steeply dissected 31—45	Mountainous >45
WETNESS (w)					
Drainage	Good	Moderate	Imperfect, temporarily high water table	Imperfect with almost permanent high water table	Poor, very poor
Flooding	FO	—	—	F1	F2 +
PHYSICAL SOIL CHARACTERISTICS (s)					
Fine earth texture/ structure	CL, Co, SC, Cs	SiC, SCL, L	SL, LSf	LSm, LSc, Cm, SiCm, Sf	Sm, Sc
Surface and subsurface stoniness	Downgrading over six sections of 25 cm using the weighting rates : 2—1.50—1.0—0.75—0.50—0.25				
Soil depth (cm)	150	149—100	99—50	49—25	< 25
FERTILITY NOT READILY TO BE CORRECTED					
Weathering stage (CEC)	Entisols Inceptisols Ultisols Oxisols (—) any (—)	Oxisols (+) —16(+)			
Base saturation		36—50	51—80	> 80	
Top soil (%)	20—35	< 20			
Organic carbon (%, C, 0—15 cm)	> 1·5	1·5—0·6	< 0·6		

* After Sys, 1982

For texture/structure, the suffixes : 0 = weak structure and consistence of the oxic horizon, s = angular or subangular blocky structure, m = massive, f = fine, m = medium, c = coarse.

Class N : *Currently not suitable.* Land units with severe or very severe limitations which may be overcome in time but which cannot be corrected with existing knowledge at currently acceptable cost.

Class N2 : *permanently not suitable.* Land units having limitations which appear so severe as to preclude any possible use of the land in the given manner.

The kinds of limitations are reflected in the land suitability subclasses.

Allowances for the consideration of current land suitability classification (without major land improvements) or the potential land suitability classification (after major land improvements have been made) are in-built within the framework.

Test applications

Soil suitability classification system for rubber

The classification of the suitability of the soils for rubber cultivation by this system has been found to be in good agreement with field experience. In the study by Chan and Pushparajah (1972) the mean yield for any of the given clones is always higher on the shale derived Munchong series soil (Haplorthoxes) and lower on the marine alluvial soil of the Selangor series (Sulfaquepts). Munchong series soil has been classified as a Class I soil and Selangor series soil as a Class V soil for rubber cultivation in that study.

Soil Suitability Technical Grouping System for Rubber

Based on a study of this Technical Grouping System by Chan *et al* (1975), it has been shown that soils with balanced composition of particle size distribution, friable consistencies, strong and moderately strong medium and fine subangular blocky structures and good drainage features, such as Munchong, Segamat and Kuantan series (all of these soils being Oxisols) scored the highest (above 72 points). On the other hand, soil units with a shallow effective depth, unbalanced composition of particle size distribution, very firm or very loose consistencies, high compaction, poor structure and poor drainage scored very low (42 — 52 points), for example, Briah series, Selangor series and Linau series (Inceptisols/Entisols), while peat (Histosols) scored the lowest (36 points). Higher technical group ratings were generally related to higher yield patterns in the field. Tables 4 and 5 summarise the system.

Land evaluation system for rubber

Land indices, obtained in the system proposed in 1982, have been shown to have yield predictive values. Higher land indices are related to the yield of rubber (Fig. 1). As such, the expected yield of rubber for various land units can be computed ; those for four land suitability classes are shown in Fig. 2.

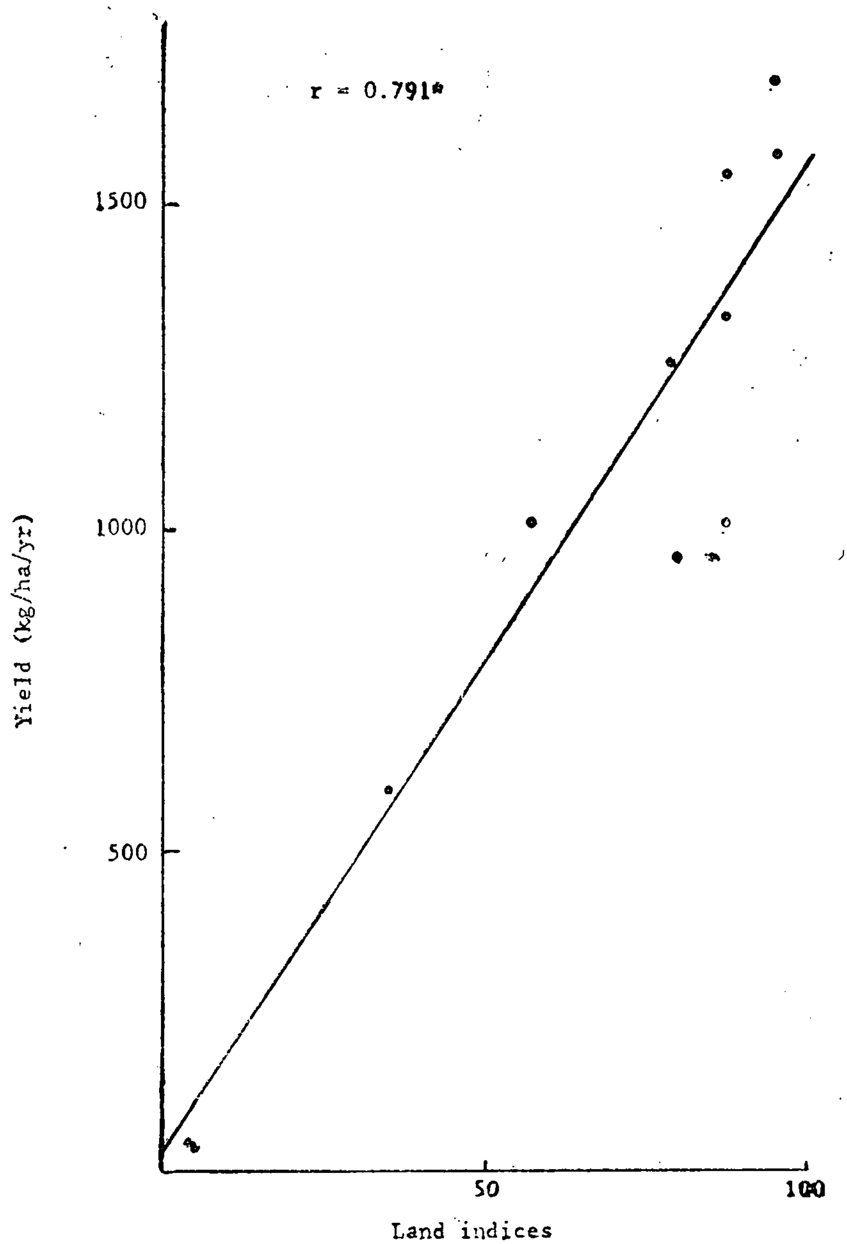

Fig. 1. Relationship between land indices and yield of RRIM 600 (after Yew, 1982).

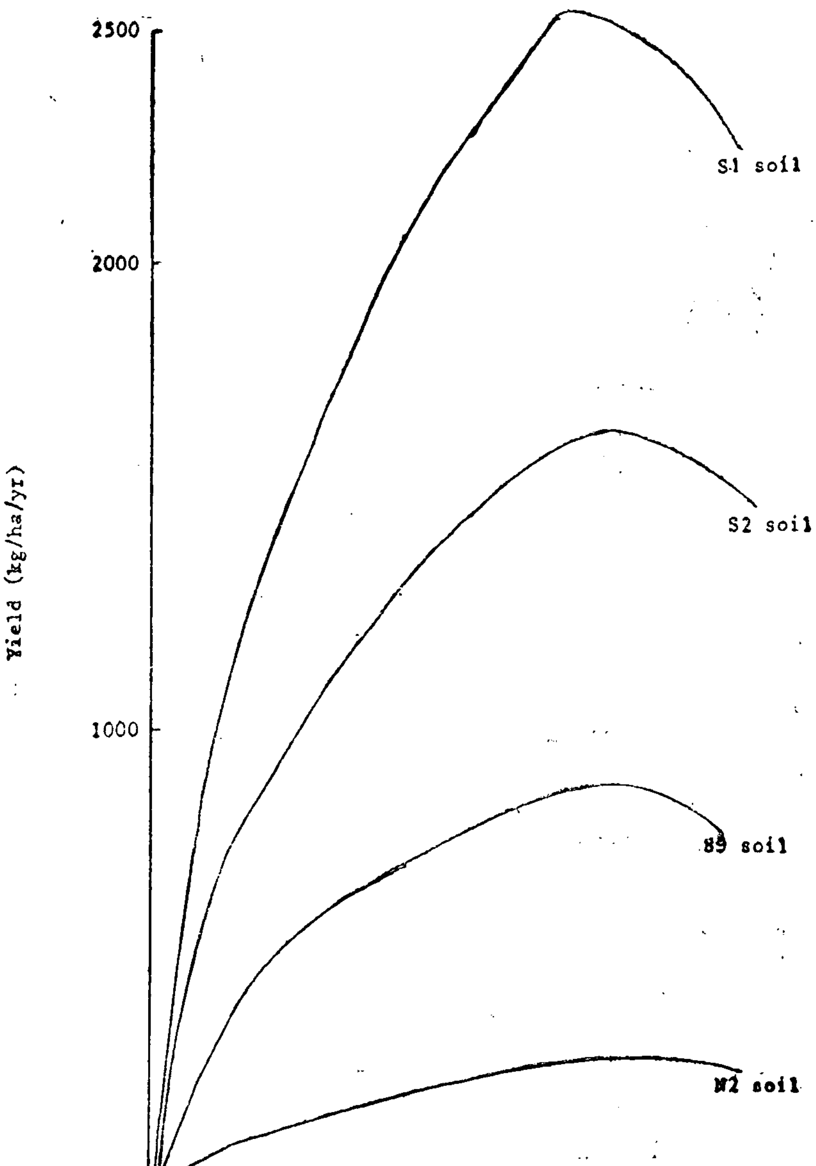

Fig. 2. Expected yield for RRIM 600 on four soils (after Yew, 1982).

Table 4. *Scores of common soils under* Hevea *in peninsular Malaysia**

Soil series	Classification after soil taxonomy	Total scores from sum of 16 differentiating criteria (maximum, total — 80 points)		Technical group rating[2]
		Scores	Relative %	
Munchong	Haplorthox	78	98	1a
Jeram	Tropudult			
Bungor	Paleudult	76	95	
Jerangau	Haplorthox	74	93	
Rengam	Paleudult	73	91	1b
Segamat	Haplorthox	73	91	
Kuantan	Haplorthox	73	91	
Harimau	Paleudult	72	90	
Senai	Haplorthox	70	88	11a
Batang Merbau	Tropudult	68	85	
Subang	Tropaquept	68	85	11b
Kulai	Tropudult	66	83	
Serdang	Paleudult	64	80	
Ulu Tiram	Dystropept	64	80	
Pohoi	Dystropept, Tropudult	63	79	
Holyrood	Quartzipsamment, Haplorthox	63	79	111
Tampoi	Haplorthox	63	79	
Lunas	Dystropept	62	78	
Kuala Brang	Dystropept	61	76	
Durian	Tropudult	59	74	
Batu Anam	Tropudult	59	74	
Malacca	Haplorthox	57	71	IVa
Pasir Puteh	Tropaquept	55	69	
Kampong Chempaka	Dystropept	55	69	
Tok Yong	Dystropept	55	69	
Sogomana	Tropaquept	55	69	IVb
Sitiawan	Tropaquept	55	69	
Briah	Fluvaquept	52	65	
Selangor	Sulfaquept	50	63	Va
Sg. Buloh	Quartzipsamment	48	60	Vb
Linau	Sulfaquept	42	53	Vc
Peat	Fibrists, Hemists	36	45	Vd

* After Chan *et al* (1975)

1 Maximum = 80 points

2 Technical group rating (by relative %)

96 — 100 la	81 — 85 11b
91 — 95 lb	76 — 80 111
86 — 90 11a	

Table 5. *Proposed soil suitability technical grouping system for soils under rubber**

Soil suitability class	Yield categories[1] kg/ha	Series [2,4]	Classification: Great Group Level — Soil taxonomy	After Thorp and Smith, 1949
I	High yield (> 1350)	(a) Munchong	Typic Paleudults	Latosol
		Jeram	Typic Paleudults	Latosol
		Prang	Tropeptic Haplorthoxes	Latosol
		(b) Segamat	Tropeptic Haplorthoxes	Latosol
		Kuantan	Tropeptic Haplorthoxes	Latosol
		Rengam	Typic Paleudults	Red and yellow podzolic
		Jerangau	Typic Paleudults	Red and yellow podzolic
		Yong Peng	Typic Paleudults	Latosol
		Bungor	Typic Paleudults	Red and yellow podzolic
II	Above average yielding (> 1200—1350)	(a) Senai	(Orthoxic)[5] Palehumults	Red and yellow podzolic
		Harimau	Typic Paleudults	Red and yellow podzolic
		Merbau	(Orthoxic) Tropudults	Red and yellow podzolic
		Batang Subang	(Oxic) Humitropepts	Hall-bog
		Kulai	(Oxic) Plinthodults	Yellow podzolic
III	Average yielding (> 1050—1200)	Serdang	Typic Paleudults	Red and yellow podzolic
		Holyrood	Oxic Dystropept	Pale yellow podzolic
IV	Below average yielding (> 900—1050)	(a) Batu Anam	(Aquoxic)[5] Dystropepts	Grey podzolic
		Durian	(Oxic)[5] Plinthudults	Yellow podzolic
		(b) Malacca	Plinthic Haplorthoxes	Latosol
		Gajah Mati[3]	Petroplinthic Haplorthoxes	Latosol
		Marang	Petroplinthic Paleudults	Grey podzolic
		Kedah	Lithic Oxic Dystropepts	Reddish brown podzolic
		Seremban[3]	Petroplinthic Paleudults	Reddish brown podzolic
V	Low yielding (> 900)	(a) Briah	Tropic Fluvaquents	Low humic glei
		Selangor	Typic Sulfaquepts	Low humic glei
		(b) Sungei Buloh	Orthoxic Quartzipsamments	Alluvial
		(c) Linau	Typic Sulfaquepts	Low humic glei-bog
		(d) Peat	Tropofibrist	Bog

1. Considering only average management standards : with higher levels of management standards and modern clones, productivity is significantly higher (Chan and Pushparajah, 1972)
2. After Chan, H. Y. 1975.
3. Included on the basis of limited data and their close likeness of physical and chemical properties to the ones studied.
4. It is qualified that there are soil variation like soil texture existing within a soil series. The physiography of the soil series can also vary, *e.g.* slope and soil depth. These variations influence yield and growth (Chan *et. at.*, 1972 & 1974). As such, the soil series mentioned in this table are the model or standard soil series only. Further investigations of such variations on *Hevea* performance will provide the basis for updating and revision of these recommendations to incorporate any necessary refinements. For current practice and purpose, it is sufficient if a plantation has its property soil-mapped at the series level. This is an essential pre-requisite for any initial proper management-planning.
5. Parenthesis under 'classification' column denotes suggested new sub-groupings.
6. No soil series name has been given to " Peat " for purposes of this paper, the general grouping of " Peat " is used.

* After Chan *et. al.* ; 1975.

SUMMARY AND DISCUSSIONS

The need to develop methods that can be used to diagnose the suitability of land for agricultural purposes, including rubber, is now assuming greater proportions of prominence. This situation has arisen in Peninsular Malaysia, whereby, with the tempo of agricultural activity increasing rapidly in the past three decades, scarcity of good land and conflicting interests arising from competition for land by various users have led to the need to evaluate land according to its intrinsic qualities and merits.

In Peninsular Malaysia, the first schematic soil classification system was suggested by Owen in 1951. Only in 1966, was the first official documentation of soil series present in the country made available. This knowledge, coupled with the information accreted over a period of time regarding the performance of rubber on various soil situations and their responses to fertilisers provided the avenue to understand better the relationships of rubber tree crop/soil adaptability and suitability.

The first Soil Suitability Classification System for rubber has been proposed of Chan and Pushparajah in 1972. The classification is based on the number and types by soil limitations and is non-parametric in approach.

Three years later, the Soil Suitability Technical Grouping System for *Hevea* (Chan *et al.*, 1975) was proposed. The approach was based on an addition of scores accorded to the evaluation of the sixteen diagnostic criteria.

Since both the systems were developed for local use, the effect of climate has been considered to be small and not significant when compared to the contribution of the soil effect on rubber performance, as shown by Chan and Pushparajah (1972).

More updated information (Yew, 1982), although cursory in nature, indicated that yield differences attributable to climate could be significant and has to be considered in land evaluation.

With an aim towards global use, an evaluation system of climate for rubber has been proposed (Yew and Sys, 1984), following the FAO (1976) guidelines for land evaluation.

A system for evaluating soils and landscape (Sys, 1982). following the same FAO guidelines, has also been developed.

A consideration of both the climate as well as soils and landscape leads to an effective land evaluation as shown by the significant relationship between land indices and yield of rubber (Yew, 1982).

An added advantage of the Land Evaluation System is that land suitability can be considered in its present state, without any land improvements (actual land suitability), or in its future state, after land improvements have been made (potential land suitability).

It is, thus, possible to upgrade a land unit to a higher potential land suitability class by appropriate agro-management manipulations and land improvements. However, the final arbiter is the economics of the operation itself.

Finally, all three systems described, can be used to group land units into suitability classes, from which expected yields of rubber production can be predicted. All three systems have been 'test-applied' and found to have agronomic logic.

Further considerations

While the foregoing has attempted to establish the logistics and soundness of the basic structure of the three crystallised systems on land evaluation for *Hevea brasiliensis* cultivation, it is likely that further precision can be derived from finer quantitative definitions in the degree of range of the considered criteria selected for evaluation. Furthermore, other criteria, based on the local experience of features common to a particular environment, may add more strength to the overall completeness of the systems. Thus, for example, the experience gained on the influence of strong winds on rubber trees on Hainan Island as reported by Huang and Zheng (1983) can form the foundation towards introducing an additional criterion into the proposed systems (Table 6) following the principles of Table 1.

Table 6. *Consideration of wind scale as an additional criterion for land evaluation for* Hevea brasiliensis *cultivation**

Degree in severity of limitation	Wind scale (Beaufort force value)	Wind damage % (as experienced in Hainan Island)
Desirable	8 and below (< 20·7 m/s)	2 — 5
Minor	9 (20·8 — 24·4 m/s)	6 — 10
Moderate	10 (24·5 — 28·4 m/s)	11 — 16
Serious	11 — 12 (28·5 — 36·9 m/s)	17 — 33
Very serious	13 and above (> 37·0 m/s)	> 33

* Based on Huang and Zheng (1983)

Point scores can be awarded to the criterion in accordance with the same principles as established in the systems discussed in the foregoing.

In the same vein, other criteria, environmental or otherwise, can be included for assessment criterion in question. However, such additions should be further confirmed by formal tests and trials.

Following the same line of reasoning, a cross-check of experience gained on a specific criterion but operating in different environments will attest further to the quantitative validity of the chosen criterion. Thus, for example, it is interesting to note that Huang and Zheng's experience that, in China, the temperature ranges of 27 — 30°C (optimum range for photosynthesis) and 22 — 28°C (favourable for latex flow) agrees very much with the desirable range for temperature as established by Yew and Sys (1984) based on experience in hot Tropical Malaysia. Perhaps, such follow-up work should form the basis of future work in land evaluation studies for rubber.

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NODULATION OF *PUERARIA PHASEOLOIDES* BY INTRODUCED RHIZOBIA IN COMPETITION WITH NATURALIZED STRAINS IN THREE DIFFERENT SOILS

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INTRODUCTION

Inoculation of legume seeds with selected strains of rhizobia before sowing is a general practice in many parts of the world. For such inoculations to be successful the introduced strain must not only be effective but also should be able to compete with indigenous rhizobia and other soil microflora.

In most of the temperate countries native rhizobial populations are very low in numbers and inoculation with effective rhizobia is an obligatory procedure in legume productivity. But this is not the case in tropical countries, specially with the *Rhizobium* cowpea complex. There is a considerable number of native flora which can compete with introduced inocula. However published information on success of strains applied as inocula in soils containing native flora appear to be lacking for tropical soils.

The investigations reported in this paper were undertaken to find competition between introduced strains and naturally occuring populations of *Rhizobium* cowpea complex under temperate and tropical conditions.

The competitiveness is generally studied by examining strains, recovered from nodules on inoculated plants. Therefore, the most important factor in this study is the identification of introduced strains in the presence of other strains.

Different methods have been used by various workers over the last 40 years for this purpose. Serology was the most commonly used method and other techniques include morphology in culture or in nature, symbiotic properties, biochemical properties, sensitivity to bacteriocins, antibiotics and bacteriophages, and use of genetic markers such as antibiotic resistance.

The usefulness of any of these techniques depends on the specificity and stability of the marker with time.

Considering the nature of my study I have decided to use genetic markers and serological markers for the identification of introduced strains.

Soils

Studies were carried out in three different soils and details of these soils are given in Table 1.

Table 1. *Details of the soils*

Soil type	Description
Lancelin brown sand (Australia)	pH 5·5 ; Nitrogen content—very low
Agalawatta soil series (Sri Lanka)	pH 5·1 ; Nitrogen content — 0·118%
Homagama soil series (Sri Lanka)	pH 4·8 ; Nitrogen content — 0·107%

Rhizobium strains

Details of the rhizobia used in this study are given in Table 2.

Table 2. *Rhizobial strains used in this study*

Strain	Description
RRISL 09	Isolated from *Pueraria phaseoloides*. Found to be effective on *P. phaseoloides*.
RRISL 09S ^{200}CL ^{100}	Streptomycin (200 ppm) and Chloramphenicol (100 ppm) resistant mutant of RRISL 09. Effective on *P. phaseoloides* as its parent
CB 756	Received from culture collection in Queensland. Effective on *P. phaseoloides*.

Production of mutant strain

Mutants were obtained as described by Schwinghamer and Dudman (1973) except that multiple steps were used in my study. When mutants had acquired the expected level of streptomycin resistance, they were subjected to chloramphenicol and their resistance developed upto 100 ppm.

Production of serological markers

CB 756 and RRISL 09 were introduced into rabbits to obtain antisera against them. Young growths of bacteria from surface of yeast manitol agar were harvested in sterile physiological saline and were injected into 6 months old rabbits at 14 days intervals. Rabbits were bled after four injections from the marginal vein of the ear.

Host plant

Pueraria phaseoloides plants were grown in plastic pots containing unsterile soils. Basal nutrients without nitrogen were added and pots were maintained at about 20% water holding capacity.

Estimation of natural rhizobial populations

The method used for counting rhizobia was the same as the five fold serial dilution plant infection test of Brockwell (1963).

Sowing and inoculation

Acid treated seeds were introduced at about 2 cm depth. Seedlings received one ml of appropriate bacterial suspension containing approximately 1×10^8 cells per ml.

Sampling

Nodule occupancy by the introduced strain after 1 1/2 months was the criterion for the competitiveness.

Rhizobial strains which were introduced to different types of soils and methods of identification after recovery are given in the Table 3.

Table 3. *Rhizobial strains which were introduced to different types of soils and methods of identification after recovery*

Type of soil	Strain	Method of identification
Lancelin sand	RRISL 09	Using the genetically marked mutant of RRISL 09.
Agalawatta series	RRISL 09	Gel immune diffusion
	CB 756	Gel immune diffusion
Homagama series	RRISL 09	Gel immune diffusion
	CB 756	Gel immune diffusion

All nodules from selected plants were pooled and 20 nodules were selected randomly from each treatment to determine the percentage of nodule occupancy by the introduced strains.

Identification

(a) Using genetic markers

Nodules were surface sterilized and streaked on yeast manitol agar and antibiotics incooperated yeast manitol agar.

Using serological markers

Growths from the nodules were used for immunodiffusion reactions. Immunodiffusions were performed in 4 mm thick gels as described by Dudman in 1964. The undiluted antisera were introduced into the central wells and suspensions of the appropriate antigens were put into two of the outer wells, diametrically opposite each other. The strains to be identified were placed in the four remaining wells.

RESULTS

Population estimations

Naturalized rhizobial populations in experimental soils are given in Table 4.

Table 4. *Estimation of naturalized populations*

Type of soil	Estimated number (Per gram of soil)	Confidence limits (95%)
Lancelin brown sand	4·0	1·2 — 12·8
Agalawatta soil series	$14{\cdot}1 \times 10^1$	$5{\cdot}3 — 38{\cdot}1 \times 10^1$
Homagama soil series	$10{\cdot}8 \times 10^1$	$4 — 28{\cdot}7 \times 10^1$

Percentage of nodule occupancy by the introduced strains in different soils is given in the Table 5.

Table 5. *Percentage of nodule occupancy by the introduced strains in different soils*

Soil type	Strain	% of occupancy by introduced strain
Lancelin sand	RRISL 09	90
Agalawatta soil	RRISL 09	35
	CB 756	25
Homagama soil	RRISL 09	30
	CB 756	20

Competitive success of introduced strains in Sri Lankan and Australian soils is given in Table 6.

Table 6. *Competitive success of introduced strains in Sri Lankan and Australian soils*

	Sample 1 Lancelin brown sand (Australia)	Sample 2 Agalawatta and Homagama soils (Sri Lanka)
No. of nodules formed by introduced strains	18	22
No. of nodules formed by indigenous strains	2	58
Competitive success of introduced Rhizobia	0·90	0·28

(This difference is highly significant, using normal approximation to binomial distribution)

DISCUSSION

These studies indicate that introduced rhizobia establish differently in different soil conditions. The introduced strains produced a majority of nodules in Lancelin brown sand in Australia and fewer number of nodules were produced by the introduced strains in Sri Lanka.

This may be due to the wide spread of cowpea type of *Rhizobium* and their high competitive ability in Sri Lankan soils. Plant infection counts revealed that Agalawatta and Homagama soils in Sri Lanka have thirty times higher bacterial populations than Australian soils.

These data clearly show why promiscuous host plants in tropical soils rarely respond to inoculation. On the other hand introduced rhizobia produced a major proportion of nodules in Lancelin brown sand with *P. phaseoloides* even though this host is a promiscuous type.

This disparity may be due to the presence of very low numbers of indigenous rhizobia in tested soils. In 1980 Ikram and Broughton also noticed the same trend with *Psopocarpus tetragonolobus* when inoculated with *Rhizobium* cowpea complex strains in soils with low numbers of naturalized flora.

These results clearly show us why introduced rhizobia under Sri Lankan conditions do not produce higher yields as in Australia or in other temperate countries.

Therefore the poor response towards the inoculation in tropical soils is mainly due to the poor competitive ability of introduced strains and not due to their ineffectivity.

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Session 10. MARKETING

INVESTMENT OPPORTUNITIES IN THE RUBBER INDUSTRIES IN SRI LANKA

By

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ABSTRACT

Sri Lanka's connection with rubber started in 1876 when Sir Henry Wickham brought 70,000 rubber seeds from Brazil to Kew Gardens, England, germinated them and brought 2,800 plants to Sri Lanka. They were planted in the Botanical Gardens at Peradeniya and at Heneratgoda where some are still alive today. These trees provided the seeds for the rubber plantations in Sri Lanka.

Natural rubber (NR) is of vital importance to the economy of Sri Lanka. Next to tea, it is the most important commodity being the second major contributor to agricultural export earnings and employment generation. The natural rubber sector accounts for about 10% to Sri Lanka's total gross export earnings and provides employment for about 500,000 persons. It also contributes a base for the production of industrial rubber products, thus providing additional employment to several thousand persons.

Investment opportunities

Table 1 shows the extent of rubber cultivated in Sri Lanka from 1904 onwards. The rapid expansion of rubber cultivation at that time necessitated the setting up of the Rubber Research Institute in 1909, and by 1930, an acreage of 235,000 hectares were planted with rubber. Please note that the acreage in 1982, 52 years later was only 206,000 hectares, well below the 1930 figure. This decrease would mean that there is now no investment opportunity for new rubber planting in Sri Lanka and only replanting. Hence future investment in the rubber industry in Sri Lanka would be,

(1) To improve our raw rubber processing
(2) To manufacture specialised grades of natural rubber and
(3) To manufacture rubber products.

Table 1. *History of cultivation of rubber in Sri Lanka*

Year	Acres	Hectares
1904	25,000	10,125
1910	118,000	47,790
1920	460,000	186,300
1930	580,260	235,005
1945	659,803	267,220
1960	668,948	270,923
1980	561,757	227,512
1981	508,685	206,037
1982	508,620	205,991

Table 2 shows the consumption of NR & SR up to 1983. You would note that in the1930's and 1940's when Sri Lanka had its maximum acreage under rubber, there was no competition from SR. Today SR is consumed at a level of 8 million tonnes and NR at a level of 4 million tonnes and we are now in no position to set standards for our natural rubber. We will have to follow the standards set by synthetic rubber producers. Dr B. C. Sekhar in his address to you said that NR deserves a price of 2 US $ a kg but is only getting one US $ a kg. Why is this ? He also said about the 3P's namely purity, processing and performance and in formulating an investment programme for the rubber plantation industry in Sri Lanka these three P's must be kept in mind.

Table 2. *World NR and SR consumption (000 tonnes)*

Year	NR	SR	Total rubber
1930	722	—	722
1940	1127	43	1,170
1950	1750	589	2,339
1960	2135	1850	3,985
1970	2990	5635	8,625
1980	3760	8685	12,445
1981	3900	8465	12,365
1982	3655	8005	11,660
1983	3940	8185	12,125

Table 3 shows the raw rubber processing facilities available in Sri Lanka. You would note that it is highly accented to latex crepe manufacture. It is predicted that because of replanting, the rubber production in Sri Lanka would reach 200,000 tonnes per year by the end of this century. It is recommended that without the addition of new latex crepe factories, the present crepe factories should be rehabilitated to run efficiently. If this recommendation is accepted, then the Rubber Controller should stop without delay the factory subsidy for new latex crepe factories.

Table 3. *Facilities available for processing NR in Sri Lanka*

	Factories				
Organisation	Latex crepe	RSS	TSR	Scrap crepe	Centrifuged latex
State Plantations Corporation (SPC)	70	61	—	5	—
Janatha Estates Development Board (JEDB)	53	30	—	6	1
State Rubber Manufacturing Company	6	—	2	—	1
Co-operatives	—	100	—	—	1
Private sector	20	71,292 roller units and 132, 242 smoking facilities	6	27	3

It would be also seen that the SPC or JEDB have no alternative forms of manufacture for latex crepe. It is possible that at times latex crepe prices will be depressed and provision should be therefore made for alternative forms of raw rubber manufacture. The SPC or JEDB should build new factories based on centrifuged latex and TSR manufacture. Dr Tillekeratne in his paper today emphasised the need for more TSR manufacture in Sri Lanka. At present no subsidy is given for centrifuged latex manufacture. The Government should decide to give approval for centrifuged latex to be included in the Factory Development Scheme to be entitled for subsidy. The necessity for subsidy for factory development is because of all the NR producing countries, Sri Lanka has the highest export duty and if Sri Lankan rubber is to get good prices, the Sri Lankan Government should divert part of this export earnings on investment in raw rubber processing to get a better return for the rubber exported.

Table 4 shows the export of natural rubber by types. It will be seen that though the small holders produce most of the raw rubber in Sri Lanka, latex crepe production was 62,000 tonnes of the 124,000 tonnes of raw rubber exported. This means that a fair amount of small holders latex is being converted to latex crepe. Dr B. C. Sekhar's first P was purity. We would normally think, that latex crepe, satisfies this requirement easily, at all stages of production till it reaches the shippers stores. We do not think so. Purity is very important. The RRI officers should visit crepe factories and recommend to the management the steps to be taken in each crepe factory to ensure purity.

Table 4. *Exports of natural rubber by types*

Year	Rubber smoked sheet	Sole	Crepe rubber Scrap	Crepe rubber Latex	Technically specified rubber (TSR)	Latex & master-batch	Total
1977	77,051	4,218	16,557	34,878	1,825	—	134,529
1978	77,434	4,569	14,111	36,776	5,156	—	138,046
1979	62,611	4,851	13,740	33,881	13,105	—	128,188
1980	60,597	4,472	8,117	38,253	8,451	52	120,942
1981	70,898	4,107	8,354	34,307	14,644	213	132,523
1982	72,040	4,145	7,342	35,850	10,788	1,156	131,302
1983	51,770	3,021	2,508	62,013	5,427	492	124,441

All flooring should be tiled, all crepe factory roofs should have a ceiling so that dirt does not fall from the roof on to the rubber, all crepe sent to brokers stores and to the auctions should be in perforated polythene bags to minimise dirt contamination in transit. As regards RSS produced by small holders it is possible to upgrade RSS in TSR factories and to bring their dirt content below 0·05%. No rubber made from latex should be exported from Sri Lanka which has a dirt content greater than 0·05%. No scrap rubber having dirt content over 0·5% should be exported. These can be implemented if we all agree that P — purity of NR is an important property to get better prices for our natural rubber.

When considering the next P *i.e.* processing, it is very necessary to manufacture Sri Lankan rubbers of different Mooney viscosities, as required by the consumer and this could vaiy from 20 to 70. This is possible by the new simple inexpensive process developed by the Ceymac Rubber Co., Ltd.

In this context it is necessary to say a few words on rubber processing. A very serious defect of NR is that it is mostly supplied at rather high viscosities whilst SR does not have this viscosity defect. Because of this high viscosity, NR has to be premasticated before rubber chemicals can be mixed into it. Premastication is both time and energy consuming. At present only a very small amount of NR is supplied as viscosity stabilised grades and even these rubbers have a Mooney viscosity of 60 and 68 which in my opinion are on the high side. If the consumers were asked to specify the viscosity, they may request a Mooney viscosity of 45 and NR producers must give the viscosity which the consumer wishes to have.

A very simple inexpensive method to obtain any required Mooney viscosity from any grade of dry rubber is urgently required and such a process has been developed by Ceymac Rubber Co., Ltd. Consideration of this must be given when future investment in raw rubber processing in Sri Lanka is considered. I would say that soon, at least 50% of Sri Lankan rubber will be exported in Mooney viscosities requested for by the consumer.

Coming now to the third P which is performance, I would state that the Rubber Chemists and Rubber Technologists have enough of academic experience and knowledge and in future their energies should be directed to visit consumers of Sri Lankan rubber, know their problems and tailor make our natural rubber so that in performance it would satisfy the consumers needs. This is done by SR producers and NR producers will have to follow suit if they wish to get good prices for their NR.

Exports of NR from Sri Lanka

More than 85% of the natural rubber produced in Sri Lanka is exported and only less than 15% of the natural rubber produced is used to manufacture rubber products. The exports of natural rubber by types during the period 1977 — 1982 have been given in Table 4.

Latex crepe

Sri Lanka is the world's largest producer of latex crepe and markets it at present on visual specifications. It is recommended that special types of latex crepe based on consumer requirements be manufactured and marketed on technical specifications. Investment opportunities exist for the manufacture of such specialised grades such as CV crepe, de-proteinised crepe etc. Yellow fraction crepe has different properties from normal latex crepe and should be shipped as a special grade preferably as a TSR grade in 33 1/3 kg bales and if necessary as a CV grade.

Ribbed smoked sheet (RSS)

RSS is mainly produced by smallholders in Sri Lanka and with the increased replanting being done by smallholders the tonnage of RSS produced will increase. Most of the RSS produced in Sri Lanka is exported in 111·1 kg bare-back bales and is not technically specified. A serious drawback of Sri Lankan RSS is its high Mooney viscosity. The value of the RSS could be further considerably improved if it can be produced as a CV grade. Thus whilst smallholders RSS currently produced is of satisfactory quality, its value can be considerably enhanced for export and its marketability improved by converting it in TSR factories as a constant viscosity RSS and exporting it as a SLR 5 (RSS) CV grade. There is considerable investment potential for this type of processing, using RSS produced by smallholders and carrying out the operation in TSR factories.

Technically specified rubber (TSR)

Technically specified rubber is exported in small bales (33 1/3 kg) in one tonne pallet crates. This type of export is suited to container shipment which is economical in freight rates. There exists investment potential for exporting converting and exporting RSS and latex crepe as TSR (CV) grades in small bales.

Sole crepe

Malaysia was the largest plantation sole crepe producer with about 20,000 tonnes in 1974 and with 8,000 tonnes in 1982. The sole crepe production in Malaysia is declining and sole crepe factories are closing down there due to the high cost and non availability of suitable labour to hand laminate the sole crepe and is expected to be below 1,000 tonne production this year. Sri Lanka can step in and fill this shortfall, as sole crepe manufacture is still profitable at Sri Lankan labour costs.

To manufacture one tonne of finished sole crepe/day would need an additional workforce of 50 persons per day over pale crepe. Since the manufacture of sole crepe gives employment to people in rural areas and earns more foreign exchange, investment opportunities for its manufacture should be actively encouraged by the Sri Lankan Government. Very soon Sri Lanka may be the only NR producing country producing plantation sole crepe. Since producing countries have not been able to meet the world demand for sole crepe, the consuming countries have been compelled to produce industrial sole crepe which is inferior in quality to plantation sole crepe. This industrial sole crepe is produced at about 20,000 tonnes annually. The annual exports of sole crepe from Sri Lanka has never exceeded 5000 tonnes and was as low as 3021 tonnes in 1983.

With proper marketing policies the production of Sri Lankan sole crepe can be easily stepped up. A reasonable target for increased sole crepe production in Sri Lanka is about 1,500 tonnes each year for about 3 years to give an increased output of 4,500 tonnes per year at the end of 3 years. Sole crepe could be considered as a rubber product and to achieve the above target it is very necessary for the Sri Lankan Government Authorities to decide to give sole crepe the incentives which rubber products enjoy at present such as duty relief, tax holidays and investment relief.

Supply of field latex, and of centrifuged latex and manufacture for export of latex based products

During the past decade, the rubber product manufacturing industries in some of the NR producing countries have experienced very rapid growth. However the only NR exporting country which exports more rubber products than importing rubber products is Malaysia. For the rubber product industry to expand there must be locally produced ancillary raw materials and also centrifuged latex available in quantity and at reasonable prices.

Sri Lanka does not produce ancillary raw materials. Because of this lack of ancillary raw materials, the rubber based products most suitable to Sri Lanka are latex based products. The latex products identified as being most suitable are dipped products, latex thread and rubberised fibre. The world needs annually 105,000 tonnes of rubber as dipped products and 35,000 tonnes as latex thread. In 1982 Malaysia exported 9,000 tonnes of rubber as dipped products and 3,500 tonnes of rubber as latex thread and earned around a billion rupees from the export of these latex products.

Sri Lanka has been very backward in this respect as regards the manufacture of latex based products. A major problem is the supply of centrifuged latex at fair prices to users. Only the JEDB and to some extent the State Rubber Manufacturing Company sell centrifuged latex, but their production is not at all enough to meet the demands of the latex based industry. Hence rubber latex product manufacturing industrialists have to set up their own centrifuges to produce their own centrifuged latex. The supply of field latex to operate these centrifuges can be got from big estates or from smallholders. Nearly all the big estates in Government hands are managed by the JEDB and SPC. The two organisations namely the SPC and JEDB are agreeable to supply field latex at 1X latex crepe prices. This is too high and private centrifuged latex manufacturers are reluctant to buy at this high price as a reasonable price would have to be worked out.

It may be mentioned that in 1954 when the rubber estates in Sri Lanka were in private hands, around 5,000 tonnes of rubber were produced as centrifuged latex and exported whilst now 30 years later even half that amount of centrifuged latex cannot be produced to feed latex based industries though the resulting products would earn on exporting a much higher foreign exchange than if the rubber was exported in raw rubber form. It is expected that a considerable amount of latex thread and dipped products manufacture would in the next decade shift to Malaysia, Thailand and Sri Lanka. The amount involved is upto 140,000 tonnes and Sri Lanka should endeavour to take its share.

The Ministry of Plan Implementation has recommended in Feb. 1981 on p13 of their report on "The natural rubber latex based industry" in section 3·5 as follows. "Since JEDB and the SPC have the monopoly of the supply of high quality field latex, an appropriate government policy making body could direct these organisations to make available estate field latex to centrifuged latex manufacturing organisations at RSS minus C O P or average latex crepe minus C O P prices, whichever is higher. Such prices could be determined on average monthly figures and announced as fixed prices for each month."

It is suggested that the above recommendation be given careful consideration and implemented as there is still considerable investment opportunities for the manufacture in Sri Lanka for latex products for export if the raw material namely centrifuged latex or field latex for centrifuging is readily available at fair prices. At present Sri Lanka does not export even 1,000 tonnes of rubber as latex based products. The main products are gloves from Dipped Products Ltd and latex thread from Multistretch. The export of rubberised fibre is also being initiated in a big way.

High export duty in Sri Lanka and its use in raw rubber processing

Of the NR producing countries, the highest duty and cesses are in Sri Lanka followed by Thailand and Malaysia with there being little or no duty and cesses on Indonesian rubber. This is one of the factors which has limited investment in the raw rubber industry in Sri Lanka. It has been recognised that part of the duty should be ploughed back into the rubber industry with a view to developing it. This is being done by way of replanting subsidies and factory development subsidies. The Sri Lankan Government subsidies for factory development is paid by the Rubber Controller for factories which manufacture a premium grade rubber after 1974 and takes the form of 1/3rd grant on approved equipment. This scheme is intended to serve as an incentive to rubber producers to increase the manufacturing capacity of rubber factories producing premium grades of rubber. The premium grades of rubber identified are latex crepe, sole crepe and TSR. This scheme was drawn up 10 years ago and needs revision to include concentrated latex such as centrifuged latex and the manufacture of speciality rubbers such as PA 80 and *Hevea* plus MG rubber and speciality latices.

Investment opportunities to manufacture rubber based products

The rubber products manufacturing industry in Sri Lanka has its beginnings in the 1930's and 1940's with the tyre retreading industry and in 1947 the annual consumption of NR was 72 tonnes. In the 1960's the manufacture of latex based products, bicycle tyres and tubes and ebonite battery boxes commenced and annual consumption rose to 807 tonnes in 1960 and 3,720 tonnes in 1970. The establishment of the Sri Lanka Tyre Corporation in 1968 which manufactures most of Sri Lanka tyre requirements boosted the consumption of NR considerably and by 1972, Sri Lanka's NR consumption was 6,109 tonnes. After 1972 efforts were made by industrialists to export rubber products but no significant achievement was possible till 1977. In 1976, 7,269 tonnes of NR was used and Rs. 4·36 million of rubber products were exported. The value of the rubber products was Rs. 225 million and provided employment for about 15,000 persons.

After 1977 because of the drastic changes effected in the economic policies of Sri Lanka, rubber product exports were developed. Initially liberalisation of imports enabled industrialists to procure vital raw materials without difficulty and to import new machinery and equipment. These factors enabled a higher quality finished products suitable for export to be produced. The establishment of the Greater Colombo Economic Commission (GCEC) in 1977 encouraged foreign investment in the rubber industry to manufacture rubber products for export. Some of the investment is from foreign collaborations who work on joint ventures projects with local industrialists and entrepreneurs. The opening of the Industrial Processing Zones (IPZ) in Katunayake and in Biyagama accelerated this investment. There are now about 180 rubber products manufacturing units in Sri Lanka of this 28 are large scale factories with six large scale factories being in the IPZ and 22 outside.

The IPZ factories cater to the export market and they enjoy certain benefits such as duty exemption on imports but are also subjected to certain restrictions, the main restriction being that they are not normally permitted to sell their products to the local market. In the past 1977 period, the output of the rubber product industry has increased from 6,700 tonnes in 1977 to 16,300 tonnes in 1981. The large export oriented factories have contributed most to this favourable change. These firms are making products such as latex thread, rubber gloves, rubber bands, canvas footwear, rubberised fibre and solid tyres.

Promotion and development of the rubber industry in Sri Lanka

It is very necessary to have organisations which understands problems and anxieties of those who have invested in the rubber industries in Sri Lanka. The GCEC is an organisation involved in the administrative setting up of rubber industries in the Free Trade Zone (FTZ). The Government organisations which can assist with technical problems encountered by the rubber products industrialists are the Rubber Research Institute of Sri Lanka (RRISL) and the Ceylon Institute of Scientific and Industrial Research (CISIR). In 1977 the Ministry of Industries and Scientific Affairs set up a Rubber Technical Service Centre under the Industrial Development Board (IDB) with the main target of uplifting the small and medium scale sectors. The necessary financial assistance for this project was provided by the World Bank and the International Development Agency. Since the accent now is on the production of rubber products for export it is now very necessary for the IDB, Technical Centre to also actively provide services for the big scale industries which are producing for export. The IDB should also assist in enabling small and medium scale industries to subcontract in the manufacture of certain items for big scale industries who produce goods for export. Further there should always be very active liaison between the RRISL, IDB (TSC) and CISIR in solving problems faced by big rubber industrialists.

Government action to develop the rubber industry

The Ministry of Trade and Shipping on the recommendation of the Export Development Board has appointed an Advisory Committee to monitor the progress and to advice on measures to be taken for the future advancement of the rubber and rubber products industry in Sri Lanka. This Committee has noted with concern the slow export growth of the rubber products industry in Sri Lanka. This Committee mentions that the absence of adequate export infrastructure, has impeded the export performance of the rubber products. Export infrastructure comprises those services which are basic to the efficient performance of export business and which individual enterprises cannot provide for themselves on an economic basis. Examples include shipping and freight handling, export credit, foreign market research, export promotion etc. Adequate provision of most of these services at reasonable rates is the proper responsibility of Government whose initiative and financial support are vital. The committee was of the view that the export of rubber in the form of finished products will give about 3 times the foreign exchange earnings of the same quantity of rubber. Hence the committee has set a target of 40,000 MT tonnes of NR for industrial consumption in Sri Lanka by 1990. This should enable 20,000 tonnes of rubber to be exported in the form of finished products from Sri Lanka.

This committee has also recommended monetary benefits, namely ;

1. Interest free loans up to 50% of the capital cost of building and machinery
2. Five year tax holiday on profits
3. Investment relief of a minimum of 50%
4. Duty free import of machinery
5. Removal of BTT on imported machinery and chemicals
6. Provision of promotional freight rates
7. Working capital at interest rates not exceeding 12%

The committee has also recommended that a Quality Control Unit be set up with UNIDO assistance to ensure adequate quality of products for export.

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THE SPECIAL PROBLEMS OF MARKETING RUBBER

By

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It was not intended that this paper bears the title it does, but reflecting on a suitable subject to speak about to a diverse group it transpired that structural difficulties, in marketing rubber emerged as if of their own accord. Such spontaneity was not to be denied, specially, if it did not fall on entirely deaf ears. It then occurred to me that I have been given a rare opportunity, to kill several birds — buyers, administrative officials, brokers and planters — with one stone. In this country there is, I was going to say, unconscious suspicion rather a very definite and conscious mistrust of the middle man who is supposed to be raking in the shekels. Licencing, customs, exchange control and every other conceivable authority looks askance at the activities of the rubber exporter. The initiated, I would have expected to look beyond cliches. Unfortunately, in Sri Lanka where the export of rubber is concerned this phenomenon is very much entrenched and is reflected in the rules and regulations the rubber exporter is subject to. Pure trade factors get more involved as does the economic background against which trade takes place.

In our day to day operations there is much criticism of the Colombo market by dealers and buyers in the major marketing centres, mostly concerning price. Justifiably so, since the same and many substitutable grades are most of the time, available at lower prices from other origins.

Without seeming to be complaining about conditions as they exist, there are however some factors which stand out that preclude us from being quite as flexible as we should be as an exporter country. Some are so fundamental that they cannot be changed in the short term, others (more) should be subject to intensive scrutiny by policy makers.

The most fundamental of these is that production in Sri Lanka amounts to a mere 140,000 tonnes a year making it one of the smaller origins operating in the international market place. The quantity available for export operations is extremely limited in the context of the structural arrangements in the international field. The exporter in Sri Lanka has necessarily to be supply dominated which in itself influences individual decisions re price by way of an inbuilt insurance. At any given time an accurate assessment of availability is crucial. While some buyers are perhaps more tolerant than others, contractual terms as they are, securing extensions on delivery periods is certainly not automatic. Permission has to be sought down the line and is not always forthcoming. Besides it is likely that all exporters have been similarly affected and a replacement impossible. This alone tends to be a restraining factor either by way, of the limiting of the quantity or increasing the price as a hedge against an unexpected change in the supply situation.

In our daily communication with marketing centres or in Market Reports it is almost embarrassing to mention flood or drought with monotonous regularity, but this happens to be so. Prudent stockpiling early this year against the historical lean period turned out the proverbial albatross and a windfall for buyers, as exporters endeavoured to divest themselves of languishing stocks, improve their liquidity position and continue operations. A more positive approach to marketing later in the year in anticipation of a weaker monsoon turned out that the rubber producing areas suffered the worst flood since 1957. Exporters spent an agonising 3 weeks thereafter endeavouring to secure quantities that were not available at high prices in turn making overseas sales at remunerative prices impossible.

Rubber plantations are almost without exception situated within the South-west quarter of the country and are by and large subject to the same weather conditions. Be it flood or drought, an alternative source of supply is just not available. Stupid as it may seem, exhaustive efforts to secure quantities for immediate commitments only result in exorbiant prices with no real alleviation of the original circumstances. Other producing countries consist of considerable land mass, with widespread acreage and as such weather conditions do not have quite the same ramifications as they do here. While weather conditions are beyond our control an otherwise assiduously attended trading position does not necessarily buffer you from other shocks. For instance, an incorrect trading decision by a larger exporter to sell short could throw the market out of line with other origins, circumscribing turnover. Stocks of the commodity previously purchased at a lower price cannot be traded profitably as they would be subject to the licensing scheme which is based on current levels.

Since Colombo is a small market, price fluctuations are wide and movements fast causing considerable distress. It is often said that wide and frequent fluctuations offer better opportunities for profit, perhaps true, but with definite limitations in Colombo in the absence of the usual tools available to traders at other origins.

The contribution the export duty makes to the misalignment of Colombo prices is considerable. At present it comprises 25% of the most expensive type of natural rubber exported from the country, sole crepe and 45% of RSS5. So much so that the lower grades of crepe rubber and flat bark crepes, are rarely marketable except at exceptional times. Export markets for these grades have been lost to Africa. Fortunately, for the producer the gap has been filled by manufacturers of retreaded tyres for local consumption. The export duty in this country is based on the Singapore price for physical RSS1 for the current month and with the usual run-up in prices prior to the position being closed out, registers an increased export duty which is reflected in the price the following week, irrespective of whether international markets for Colombo grades are firmer or easier.

Since a terminal market does not exist in Colombo and exchange control regulations prevent arbitrage, no hedging facilities are available. The idea has been mooted and perfunctorily examined but no information is forthcoming whether an intensive study has been carried out. The Colombo market is now expanding to include manufacture of rubber based goods and the full spectrum of requisite participants is available for the efficacious functioning of such a market. The presence of such a facility would considerably extend the operation of marketing. Producers in a better position of a more predictable return are likely to develop a more benign attitude to forward business and to be less intransigent. At present forward operations particularly in the better grades of latex crepe are wholly inequitable with an open-ended price mechanism. It can be reasonably expected that the setting up of such a facility would considerably mellow the extremes the Colombo market is so frequently subject to. If their buying programmes at present are anything to go by, the securing of raw material by industrialists on the physical market alone seems a nightmare. The duel operation on the contrary would make for a more constant cost factor of their raw material.

Many of you are aware there is a licensing scheme in operation in Colombo and is operated by the Department of Commodity Purchase, for and on, behalf of the Department of Exchange Control. For all the crepe grades and sole crepe the scheme is based on the price paid at the bi-weekly auctions. The scheme for ribbed smoked sheet is based on the prices paid on the London physical market. The scheme itself is probably necessary as malpractices are not unknown and is a safety net and an inducement to aspiring rubber exporters, which is in line with government policy. From the purely commercial point of view the disadvantages are obvious particularly the scheme for crepe rubber which presupposes a back-to-back operation. This could not be further from reality. The kind of organisation required to trade in rubber costs a great deal of money as does the actual operation including finance, store facilities, communication and staff. By the time operating costs and overheads are added to the price of the rubber, overseas offers can be expensive.

There is no secret about the fact that exporters live on taking views, more correct ones than incorrect. All other factors being equal, exporters endeavour to buy rubber when they consider it cheap and sell when they conclude indications or bids are thought of as high. Between the two operations much can happen and an exporter can end up, selling at lower levels than cost and is eventually a salvage operation, when every month the rubber lying in a warehouse between purchase and shipment costs 20 cents per kilo per month. Neither is the commodity merely subject to supply and demand. The comment is increasingly heard that rubber exporters are now trading more in currencies with which they are not entirely conversant.

Freight allocation in and out of Colombo is controlled by the Central Freight Bureau and whereas the overall management has resulted in a high degree of rationalisation in the port, the bias is in favour of shipping lines. They have aggressively monitored freight rates protecting exporters from arbitrary increases and with an effort at remunerative operations both for the lines and the users. The exporters' more parochial interests are not however served by way of competitive freight rates. The present system in its very essence does not permit the existence of non-conference vessels with the competition thereby implied. This facility, from all reports, exists at other origins enabling them to ship their produce at lower rates. The freight component in export prices from Malaysia & Indonesia, are 8·5% and 8% respectively compared to Sri Lanka's 9·5%.

Financing in Sri Lanka comes very expensive and it could hardly be believed that in a country so dependant on its exports, as Sri Lanka is, rubber exporters are given so little encouragement in moving out of the country one of its major cash crops. Packing credits have been available for sometime and give some relief though they are restrictive in operation. A comparatively new re-financing scheme for export is in operation though this too is limited. The insterest rate payable by rubber exporters in Sri Lanka is an average 20% compared to 13%, 6% and 17% in Malaysia, Indonesia and Thailand respectively. The best evidence of the inadequacy of financial support from the banking system is seen during the major and minor cropping seasons *i.e.* usually December/January and July/August, when after periods of substantial rainfall there is a marked increase in the arrival of rubber in Colombo and are perennial periods of lower prices irrespective of international markets. The only way exporters can tide over these periods is to offer lower prices overseas in an effort to move the commodity which operation the more astute buyer is well aware of. If for any reason the shipment schedule is dislocated, it is common to find big exporters sitting out the auctions. This occurrence continues year-in year-out and means a lower price for the producer and does not necessarily mean a fruitful time for local exporters but cheap procurements for overseas markets.

The emerging importance of local industry as a market factor cannot be underestimated. Upto 1977 rubber based industry in the country accounted for a negligible amount of the total rubber produced and was a mere 6,800 tonnes. The most upto date figure that of 1983 indicates that 16,500 tonnes equals 12% of our production is now consumed locally. This has had a considerable impact on the price structure. The absence of a terminal market necessitates that the industrial consumer ensures a continuous availability of the raw material by stockpiling their requirements and this they do with the finesse of a steam roller. The international rubber market is far more sensitive to costs and with the previously mentioned conditions also taken into consideration, certainly leaves the exporter at a disadvantage except for when shipment oriented hysteria prevails. Many of the crepe rubber grades are now preserves of local manufacture. At the beginning local industry produced green parrots, balloons, erasers and rubber bands all of indifferent quality. Now it runs to the manufacture of tyres, retreading included, masterbatch, rubber thread and dipped goods to mention just a few. The manufacturers of technically specified rubber invade the auctions for fodder and conventional rubber is in no position to compete with the incentives given to the marketing of these comparatively new grades. When the phenomenon commenced local manufacturers were limited to the lower grades of scrap crepe rubber which were in any case labouring under the high level of export duty payable. Their operations have intensified and widened towards the more sophisticated and their requirements now run to the full gamut of scrap crepe grades and well into the lower grades of latex crepes. We have on occasion seen a situation where the lower grades required by local manufacturers are at a higher price then the next best grade required by the exporter.

It must be made very clear at this point that value added operations with their socio-economic ramifications are well understood as desirable and not a complaint but meant to illustrate the impact these operations have on overseas prices.

BROKERS ROLE IN THE MARKETING OF SRI LANKA RUBBER

By

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With the rapid expansion of the rubber industry from the early 1950's and the growth of the activities of the exporters, broking activity in the country has expanded. Colombo is the centre for rubber broking activity and all Companys, partnerships and individual organisations dealing with such activity operate from this centre. Structurally brokers in Sri Lanka could be classified into two groups :

The more organised system of broking Companys handling state owned produce and those from private proprietory plantations. Majority of these firms are members of the Colombo Brokers Association whilst a few operate outside and handle a fair share of business.

The other group of brokers who carry on this function mainly in an area popularly known to the rubber trade as " GRANDPASS " are mostly partnerships and individuals. A broad distinction is that the larger and more organised form of broking firms whose expertise date back to the early 20th century handle rubber produced by the two large state organisations, JEDB & SLSPC and the produce of private proprietory owners where often the extent of the land is limited to 50 acres and less. These broking firms between them handle nearly 40% of the rubber produced in Sri Lanka. The main broking firms sell their rubber through the auction system which is the pivot on which the rubber market revolves. The other category of brokers activities are confined to the rubber which trickles into the city from the outstation dealers who in turn purchase from smallholders in rubber growing areas. They perform a very useful function and help the dealers to dispose of their rubber. Millers who manufacture low quality scrap crepes also seek the assistance of these brokers to sell their rubber. They are also engaged in negotiating forward sales on FOB contracts.

A limiting factor to the organised system of broking is that a large amount of rubber bypasses the auctions. The 1983 statistics reveal that out of a total production of approximately 133,000 m tons a quantity of around 54,000 m tons was sold through the auctions. Rubber which bypasses the auction was disposed in the following manner.

(a) Purchased by the Commissioner of Commodity Purchase
(b) Despatched by outstation traders and dealers direct to the shippers
(c) Shipped directly by the producers
(d) Sold forward by the main brokers in Colombo
or (e) Sold by manufacturers direct to local consumers as liquid latex.

The methods by which the rubber brokers perform their rubber marketing functions

(a) The Auction System
(b) Forward Sales
(c) By Private Treaty

It is through the auction system that the brokers perform their most important marketing function. The Colombo rubber market had its origin at the outset of the 20th century with the first rubber auction taking place on 4 November 1910. Since then from a mere 22 tons, currently on the average almost 800 to 1,000 tons comes under the hammer weekly. The auction system is the most organised method of marketing rubber in Sri Lanka. The conditions of sale are laid down by a set of rules formulated by the Ceylon Chamber of Commerce. Even where the sale of rubber is effected outside the auctions (FOB, Forward Delivery & Private Treaty) the conditions or sale and forms of contract tend to remain the same. The brokers conduct these sales having obtained an Auctioneer's license. The types of rubber auctioned are mainly crepe, scrap crepe, sheet rubber and sole crepe.

Prior to auctioning the rubber, a lot of preparations are made by the brokers. The work may appear to be routine but a lot of expertise is involved in the initial preparations with well trained staff at hand to assist in the work. Samples have to be drawn from daily arrivals of consignments, invoiced and despatched from rubber plantations. These numerous samples of different types of rubber which illustrate the quality of the bulk and are finally examined by the buyers prior to purchase at the auctions comes under the careful scrutiny of the brokers who in keeping with the standards laid down by the "Green book" grade and value the rubber. The catalogues depicting the "Garden mark" invoice No. and grade despatched by the estate are prepared by brokers and made available to the entire trade. Buyers make use of these catalogues to purchase rubber offered by the different brokers.

Although market trends, the general demand and the degree of competition affects prime levels at the auctions, brokers try hard to elicit the best possible bids. When the market is bouyant activities at the auctions could be most vociferous with the brokers having a nightmare of a task picking out the bids. Whilst on a day when the market sags, he has the unenviable task of extracting prices from equally determined buyers who would like to purchase goods at the cheapest possible level.

Price levels obtained at the auctions after weighted averages have been worked out are the official quotations and are published in the news papers. These price levels directly influence all sales of rubber outside the auction system. Auctions do have their dull periods but more often active conditions are experienced and the conditions generated have resulted in producers benefiting by way of enhanced prices. The presence of new competitors who give the traditional buyers a good run for their money and the recent increase in demand by the local consumers have been heartening to the producers. With the liberalization of the sheet rubber trade arrangements were made for this commodity to be auctioned after a long lapse. During the inaugural year, the total sold was only 7,339 m tons whilst in 1983 the quantity increased to 21,515 m tons. Bulk of the large buantity of sheet which bypasses the auction is brought directly to shippers godowns by outstation dealers whilst a small quantity is purchased by the Commissioner of Commodity Purchase through his depots located in rubber growing areas. The auction prices have been at higher levels and the smallholders should be encouraged to bring their rubber to the auctions in order that they may benefit by competitive prices. It is encouraging to note that the Rubber Research Institute (RRI) together with the Export Development Board have launched a scheme whereby smallholders are currently being assisted in manufacturing better quality grades. Brokers too have pledged their support to assist them in grading and sorting sheet rubber.

In grading and evaluating the different types of rubber despatched for sale by public auction and forwarding character reports to the producers, the brokers are able to highlight any shortcomings in the quality of the produce. A thorough scrutinity by the brokers helps to identify dullness in colour or the presence of blemishes and the extent to which defects show up. Sri Lanka has the purest form of latex crepe and if adverse comments have to be made on manufacture, it is with the intention of improving quality. It is to the credit of the guardians of our better managed estates battling against natural elements such as unpredictable weather patterns, difficulties in manufacture caused by bulking different varieties of latex and machinery breakdowns. Sri Lanka has yet been able to maintain a remarkable consistency and supremacy in the white crepes.

Rubber could be sold forward in Sri Lanka for a period upto 6 months for Export Duty registration purposes. The quantity handled by the Colombo Brokers may vary between 8,000 to 9,000 m tons annually with the types sold being mainly crepe, scrap crepe, thick and/or thin crepe, sole crepe and technically specified rubber. Currently forward contracts are negotiated in a particular grade at a fixed price or a premium over prices obtained at the auctions for that particular grade. By selling forward taking into account various market factors such as production, weather and other influences, producers are able to program their tasks more efficiently by ensuring the sale of quantities of rubber at attractive price levels for forward months which ensures both a profit as well as the smooth programming of the variou necessities of the estates concerned. Brokers in keeping with market trends make daily efforts to elicit interest at advantageous levels and keep estates covered with forward contracts. An after sales service too is rendered both to the buyers and sellers when attempts are made to overcome problems connected with delayed deliveries and manufacture of quality rubber. By syphoning rubber against forward contracts arrivals at the public auctions could be curtailed thereby ensuring stable price levels.

Currently a commodity which commands a premium over all other grades namely sole crepe is manufactured essentially against forward contracts. However production has remained stagnant and restricted to approximately 4,000 m tons annually. The belief that sole crepe has a good future was strengthened by the news that Malaysia, perhaps the largest producer of plantations sole crepe has curtailed their production. The feeling prevails in Sri Lanka that we could capture a share of the market. However market information should be obtained whether a genuine demand still prevails for Plantation's sole crepe. Furthermore the bulk of the sole crepe produced in Sri Lanka is the narrow gauge type measuring 13″ X 36″ whilst only a handful of estates manufacture the broader variety. For several estates that used to manufacture sole crepe upkeeping outdated machinery has been a real problem whilst recent high price for blanket crepe which narrowed the price differential between the two grades lead to abandoning this pursuit.

Selling forward upto a month or two has been a real constraint. Producers have currently realised the value of having long term forward contracts, the lack of which poses problems to the manufacturer's who are compelled to find alternative employment for a large workforce engaged in the production of types such as sole crepe. The shippers, too will welcome this idea of obtaining forward contracts covering a 5 to 6 month period, since they can assure their clients overseas of a continued supply. Buyers overseas have a habit of restricting their purchase to certain sole crepe estates which have acquired a reputation for consistency in quality. However even lesser known sole crepe estates too could produce extremely good rubber and with sellers now engaged in rehabilitating and improving machinery and assisting the factories which abandoned this lucrative pursuit, manufacture is bound to increase whilst one can hope for consistency in the standards of manufacture.

The inability of the seller to honour contracted obligations results in shipping commitments of buyers getting disrupted. This leads to heavy penalty claims from overseas clients. Delay in deliveries is more often due to the location of rubber growing areas in the South West Zone of Sri Lanka which comes under the influence of unpredictable weather patterns. Buyers cannot be expected to carry buffer stocks to counter this problem due to high financing costs.

Sales by private treaty are rare and confined mostly to withdrawn lots at the Public Auction and unmanufactured scrap rubber.

Regular weekly visits are undertaken by the Brokers to both buyers and sellers offices where market information is exchanged. More often broker's advice has been invaluable to the estates when visits are undertaken in order to improve standards of manufacture in relation to trade requirements. When disputes arise between the buyers and sellers in matters connected with defaults and claims the Broker is called upon to arbitrate and often provides a speedy solution.

When rubber is sold by Public Auction the Brokers ensure that the seller is paid the full value of the Invoice by the " PROMPT DAY " which means 7 working days after sale. Buyers too are expected to pay within this period. The rubber Broker is often the " Financer " advancing payments when produce is delivered to his godowns.

Brokers participate in numerous meetings held by organisations such as the CRTA to discuss matters affecting the trade. Highlighting and drawing official attention to any shortcomings that prove detrimental to the trade.

Market information is provided by the Broker to the entire rubber trade by means of weekly, monthly, quarterly and annual publications. The reports call for intensive and laborious collection of data. Heavy subscriptions are made to various publications required to keep the seller well advised of market conditions.

A little known fact of a broker's service is the information he is called upon to provide various individuals and organisations outside and within the country. These sources such as the World Bank in the USA look to the Brokers for impartial views and statistics.

Brokers also perform many functions ancillary to the broking business such as the provisions of storage facilities for a consideration. Many broking firms have provided warehousing facilities to the trade when there was a dire need for good storage in the city thereby rendering an invaluable service.

SESSION 11. ECONOMICS OF RUBBER

NATURAL RUBBER: PAST PROBLEMS, FUTURE PROSPECTS

By

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For the year in which natural rubber (NR) research started in Sri Lanka, world NR consumption was 90,000 tonnes. Since that time it has grown to just under 4 million tonnes, the average annual growth rate over these 75 years being 5 per cent. This is superficially a record of steady if unspectacular growth, over a long period which has seen two world wars and a number of sharp reversals in the world economy.

This picture of steady growth ignores, of course, the impact of the synthetic rubbers (SR). Unknown in 1909, save as chemical curiosities, world production and consumption of SR did not start on a serious scale until the early 1940s, and SR consumption overtook that of NR in 1960. Today, NR constitutes only some 32 percent of the "elastomer" (NR + SR) market. Evidently NR has lost ground in the sense that its production has not been able to match the growing demand for elastomers. The question we have to ask is where, roughly, will NR be by the end of the century? Will its market share be about where it is now?... or will it have fallen even lower?... or is there a possibility that it could increase?

The 1970s

A spectator of the NR/SR scene during the late 1960s might have concluded that NR's days were numbered — and indeed this view was held by not a few. By 1970, NR's share of the world elastomer market had fallen from 100 percent pre-1939 to under 30 percent, in virtually a straight line. Given this, given various technical improvements with SR, and given also the great economic attraction of low-cost SR from low-cost oil, it would not have been difficult to conclude that NR was doomed to steady extinction — or, to be less pessimistic, that its share of the elastomer market would fall to some very low residual value representing the minimal usage of NR in a few applicational areas for which SR was technically unsuited.

The "oil shock" of 1973 — and repeat performances since then — changed the picture. The view taken by many commentators at that time was that escalation in the price of oil was a "bonus" for NR, in that it would greatly improve the competitiveness of NR. Was this a correct view? In one sense, yes: the cost-dependency of NR on energy is only some 10 percent of that of SR, and the astronomical increases in energy costs since 1973 have of course considerably increased the production costs of SR *vis a vis* NR.

This, though, is only half the picture. The 1973 and 1979 oil price increases — and the subsequent series of shock waves through the world economy — had a major effect on the demand side, an effect which can be very simply illustrated. Over the decade of the 1960s, world elastomer consumption grew at almost 7 percent/year, and had in fact done so since shortly after the end of the 1939 — 45 war. Since 1974 to the present time, the annual growth rate has been little more than 1 percent : external events during the 1970s virtually destroyed growth in the world rubber industry.

These events have harmed NR far more by their adverse effect on consumption than they have helped by improving NR's production cost competitiveness. NR, like SR, has had to struggle to exist in a world of declining markets. The very sluggish growth in the world elastomer market to which reference has just been made had the effect on NR that consumption actually fell for 3 years in succession over 1979 — 1982, and there was a price drop of 1000 M$/tonne over 1980 — 1982.

Potential for the future

In fact, as far as market share is concerned, there has been some evidence for an improvement in health in recent years : NR's market share has moved up from a low of 29·8 percent in 1978 to almost 33 percent today. This, though, is largely a response to the very low NR price over much of this period, and this short-term trend could reverse if the NR price were to rise substantially over that of general-purpose SR. We need to look for more substantive signs of permanent health.

Such a sign can be gleaned from a study carried out in the early 1970s by the Malaysian Rubber Research and Development Board on behalf of the ANRPC, to assess the potential market for NR. The purpose of this study was to try to assess what level of share would accrue to NR if could it compete on level economic terms with SR (and provided, of course, that NR production could be expanded). The outcome of this study was the "techno-economic norm" : a sensible estimate of the market share that NR might aim to achieve. This norm was at that time calculated to be 43 percent for the world (excluding the Communist-bloc countries), the upper limit being 50 percent. The minimum NR market share was estimated to be around 30 percent.

The conclusions of this earlier study are reinforced by what now appears to be the pragmatic view of the rubber industry, that the elastomer market divides up on technical grounds into 40 percent for NR, 40 percent for general-purpose SR, 10 percent for special-purpose SR, the remaining 10 percent being open to competition on the basis of price. Disregarding the precise percentages, the point to be made is that the decline in NR's share of the market in recent decades is reversable ; there is a lot of life left in NR, and its full potential has yet to be realised.

Several contemporary features of the world elastomer scene, in fact, reinforce in a very tangible way the supposition that NR, far from being a commodity of diminishing value, continues to be of vital importance. Particularly significant is growing concern among major consuming regions over the security of the future supply of NR. This is evidenced by (1) moves in the USA to increase the US strategic stockpile of NR to 850,000 tonnes, (2) continued interest in the potential of *Guayule* to provide another source of natural polyisoprene, and (3) the long-term intention of the USSR to develop a very large productive capacity of synthetic polyisoprene.

If NR is technically a " has been " then these situations would not exist. The USA, for example, with its prodigious technical and financial skills, would surely not be at all interested in maintaining large domestic stocks of NR if it were a simple matter to use some other elastomer. Current interest in *Guayule* (mis-placed though some of us in the *Hevea* business think this to be) would not exist unless there is the belief that polyisoprene rubber is a much needed commodity. The USSR approach further underlines the correctness of this view, even though their choice (for reasons that need not concern us here) lies with the synthetic version of NR, a choice which is certainly ruled out in the West by economic factors. The world, then, shows every sign that it will continue to want polyisoprene rubber. Since *Hevea* is without doubt the best all-round producer of polyisoprene (disregarding special situations) the prognosis for our industry can only be regarded as good.

Possibilities for 2000 AD

In order to arrive at some idea as to the likely NR share of the world elastomer (NR + SR) market at some future date it is necessary first to assess future elastomer demand. This is no easy matter, and it has been made much more difficult by the prolonged slump in demand since 1973 to which reference has been made. For this reason, forecasts made by various expert bodies over recent years have given progressively lower estimates for 1990 and 2000 as each year passes.

Forecasts produced since 1979 by the IRSG, the IISRP and others (including a comprehensive econometric study by the Dutch Economist, H. P. Smit), have given estimates for the year 2000 ranging from 14·3 to 21·7 million tonnes. Very recently, the " Task Force " appointed in 1983 by the Minister for Primary Industries in Malaysia has come up with the figure of 18 million tonnes, with a probable error of +/- 3 million tonnes. This can be regarded as a sensible, middle-of-the-road, benchmark.

If the NR producers were to aim to increase the NR market share from its present level (32 percent) to say 40 percent — and, as indicated, this is feasible on techno-economic grounds, then NR production would need to be over 7 million tonnes/year by 2000. The present (1984) production rate is about 4 million tonnes/year, and it is inconceivable that production could be increased by 3 million tonnes/year in the intervening 16 years.

The Malaysian Task Force suggests that the demand for NR in 2000 will be 6 million tonnes/year. This figure is reinforced by the econometric study just referred to, which includes analysis of NR production, using a method whereby allowance is made for the age and type of planted trees and hence of their future production potential ; this gives 6·15 million tonnes/year for NR production in 2000.

Accepting all the hazards of forecasting, all that can be said is that the consensus view of experts at this time is that, for the year 2000, world elastomer consumption will be about 18 million tonnes and NR production about 6 million tonnes. On this basis, therefore, NR's share of the market is expected to be 33 percent, distinctly higher than the ' low ' of 1978 and somewhat higher than the present level.

The outcome is quietly encouraging. Production constraints make it impossible that NR should rapidly regain a very much larger market share ; on the other hand, the various forecasts do all indicate that the share will certainly not diminish but will stabilize, moving up just a little. This reinforces the view put forward earlier, that NR remains an important and valuable commodity, and there is no case for pessimism as regards market share.

Requirements for growth : the production scene

To achieve the production level just indicated — 6 million tonnes/year by 2000 — will require careful and concerted effort on the part of the producers. Also, it must be said — very firmly — that producers are not so much interested in tonnages and market shares as in value (price times volume). For this reason, attention needs to be devoted to the nature and composition of NR consumption which — it will be shown — has an important bearing on price.

On the production front, the "name of the game" will be *production efficiency*. In most producing areas, opportunities for turning over new land to *Hevea* are becoming increasingly limited ; there are other uses for land (other crops, industrial uses, housing) and the days when production of NR could be boosted by planting trees on newly-cleared jungle land at low levels of productivity are gone for ever. There is also a growing shortage of labour. The need therefore is to extract the maximum quantity of NR from existing areas (or even diminished areas) with no more (and if possible, less) manpower than that presently used.

Two observations are pertinent. The first is that, despite the many years' work on tree breeding since the inception of the Institute in Sri Lanka, average yields around the world — as low as 200 — 300 kg/ha/year in some areas — are far below the best achieved in some areas (over 1000 kg/ha/year) and even these are less than the potential. The second is, to quote from the Malaysian Task Force Report, that "...the tapping and collection practices commonly practised today with the exception of the use of yield stimulants are more or less those of 50 years ago".

As far as trees already in the ground are concerned, the need is to optimize productivity by making use of well-known and proven methods. There is no doubt that if the full potential of these trees can be realised, future production could meet future demands at the level postulated. For example, reduction in the frequency of tapping (from d/2 to d/3) plus use of yield stimulation can, according to recent Malaysian experience, reduce the labour requirement by some 40 percent while maintaining or increasing the yield. Also, further development of mechanized tapping and collection methods is called for.

As far as future of replanting is concerned, an imaginative approach is called for, coupled with full use of existing know-how. There is need to make much wider use of techniques such as those which reduce the period of immaturity, precocious yielding clones, three-part trees, optimal planting densities, and so on. All of these are well-known to the industry. The problem seems to be that knowledge of all such methods is not matched by its application.

For the longer term, there is of course the need to extend the potential of *Hevea* by breeding research (with, for example, the 1981 material collected by the IRRDB in Brazil and now being distributed) and allied activities (*e.g. in vitro* cultivation techniques). For breeding, the target should be, not merely productivity, but adaptability to special conditions, and resistance to diseases (especially SALB).

Overall, the plantation industry needs to take a wider view of its purpose. Instead of regarding itself as a producer of NR, it should plant *Hevea* with the intention of using the (reduced) immaturity period for the growing of cash crops, it should collect and use seeds during the 20-year life cycle of a tree for cattle feed, and it should use the tree at the end of its life as timber. Such an integrated approach will not only enable NR production to expand as envisaged, it will also greatly improve the socio-economic contribution of the industry to its country. The technologies to do all of this exist, the need is to employ them.

In general, the position appears to be that, despite the existence of a wide range of methods for improving production efficiency, these methods are not being implemented as fully or as widely as is desirable. Is there a "communications gap"? If so, the IRRDB is willing and able to help fill it.

Requirements for growth : the consumption scene

In this section, attention is focussed on *patterns* of NR consumption, and on the influence that these patterns have on the economic status of NR.

As far as the NR producers are concerned, the influence of consumption on their well being is more diffuse and less obvious than is the influence of production changes. In respect of production, the producers are obviously their own masters, but they cannot dictate in what ways their NR should be used. All that they can do is to seek to persuade and encourage, by providing appropriate information to consumers.

Tyres are the dominant sector of NR consumption. Over the past 20 years, the tyre industry's share of NR consumption has risen from under 60 percent to 73 percent (for the major industrialized countries taken together) ; this is a result of (i) conversion from cross-ply to radial-ply construction, and (ii) the increasing production of truck tyres *vis a vis* car tyres. There is no doubt that this trend will continue. The Malaysian Task Force suggests that, by 2000, tyres will require an additional 2 million tonnes/year of NR compared with 1982 ; this is about 80 percent of the total postulated increase in NR consumption over this period.

It may well seem that this situation — whereby one consuming sector virtually "guarantees" taking most of the projected production increase — is very satisfactory. To an extent this is so, but there is another feature.

As between the tyre and "non-tyre" sectors of the NR market there is an important difference. NR/SR compositional requirements for tyres are not very responsive to price changes. This is not true in the non-tyre sector, where there are many "technically undemanding" applications for which either NR or SR can be used, according to price. ("Technical" applies to processing requirements as well as to service performance).

The dominance of the tyre sector ensures that its consumption largely determines the NR price, other things being equal. When there is a surge in demand for tyres, the tyre manufacturers have to find the extra NR either from world stocks or by (as it were) " stealing " some NR from the non-tyre sector ; this cannot come from extra NR production because this is unable to be increased in the short term. The NR price will rise, and this will encourage consumers in the non-tyre sector to switch from NR to SR. Unfortunately — and this is the important point — when tyre demand slackens, there is evidence that the reverse process (switching back from SR to NR) in the non-tyre sector is not so strong. Thus, the existence of " technically undemanding " applications in the non-tyre sector has the effect of restraining the price rises which would otherwise occur as a result of booms in the tyre industry.

As regards NR consumption, then, the requirements for healthy growth are :

(1) to continue to foster usage of NR in tyres by means of appropriate R & D and promotional activities, on the basis that it would be absurd to neglect or ignore this dominant sector. It is especially important to be aware of possibilities for major substitution away from NR in tyres, and to carry out appropriate work to guard against this.

(2) to develop a portfolio of non-tyre applications which are technically *demanding*, so as to strengthen this sector of the market.

Concerning (2), the need is not only to establish new applications for NR which uniquely require it, but also to encourage use of added-value forms of NR.The former includes, for example, high-durability engineering components ; the use of NR in these is already respectable (some 100,000 tonnes/year) and needs to be increased. The latter includes materials such as thermoplastic, powdered and liquid forms of NR. Production and usage of these materials will help to strengthen the NR market, and it is especially desirable that their production should be concentrated in the NR producing countries.

On this last point, it is important to appreciate the scale and significance of the changes taking place in the geography of NR consumption. Over the past 20 years, 50 percent of the increase in NR consumption has taken place in the developing countries, including those that produce NR. Of particular significance is the fact that consumption within the producing countries (about 8 percent today) is rising fast. This trend, in addition to serving the purposes of the countries themselves, is an important factor which serves to strengthen the market for NR.

Final points

The long-term outlook for NR is quietly promising ; there is certainly no cause for pessimism, despite the problems of recent years. NR producers can, if all the expert prognostications are correct, expect to see annual consumption rise from the present level of 4 million tonnes/year to about 6 million tonnes/year by AD 2000, and this will maintain NR's share of the world elastomer market at slightly above the present level.

To achieve this production increase in a manner which will satisfy the national and individual needs of the producers will require strenuous efforts to improve production efficiency. It will also require the fostering of new outlets for NR in non-tyre applications so as to strengthen the market. Both aspects will require considerable inputs of R & D.

Of course, no one can guarantee that there will not be problems ; for example, another round of world depression. Short term problems (let us hope that if they occur, they will be short-lived) affecting the NR price can of course be coped with via the INRO price stabilization operation. This latter, plus the longer term measures advocated in this paper, should together enable the NR producers to face the future with confidence.

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NATURAL RUBBER SUPPLY IN SRI LANKA: ANALYSIS AND PROJECTIONS USING VINTAGE APPROACH

By

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General information

Sri Lanka produced about 100,000 tonnes of natural rubber (NR) until the middle of the 1960's (cf. Fig. 1.1). Sri Lanka was the fourth largest natural rubber producing country with 4 to 5 percent of world NR production. However, it lost its fourth place to India in 1980 while its NR production declined from 152·7 thousand tonnes in 1979 to 133·2 thousand tonnes in 1980 (see Table 1.1) or 3·5 percent of world NR production, with even lower levels in 1981 and 1982. What are the reasons behind these developments and what will be the future ? That is the subject of this paper.

Table 1.1. *Production of NR in Sri Lanka (1,000 tonnes)*

Year	Production
1955	95·3
1956	96·9
1957	99·7
1958	101·8
1959	93·2
1960	98·8
1961	97·6
1962	104·1
1963	104·8
1964	111·6
1965	118·3
1966	131·0
1967	143·2
1968	148·7
1969	150·8
1970	159·2
1971	141·4
1972	140·4
1973	154·7
1974	132·0
1975	148·8
1976	152·1
1977	146·2
1978	155·7
1979	152·7
1980	133·2
1981	123·9
1982	125·2
1983	139·9

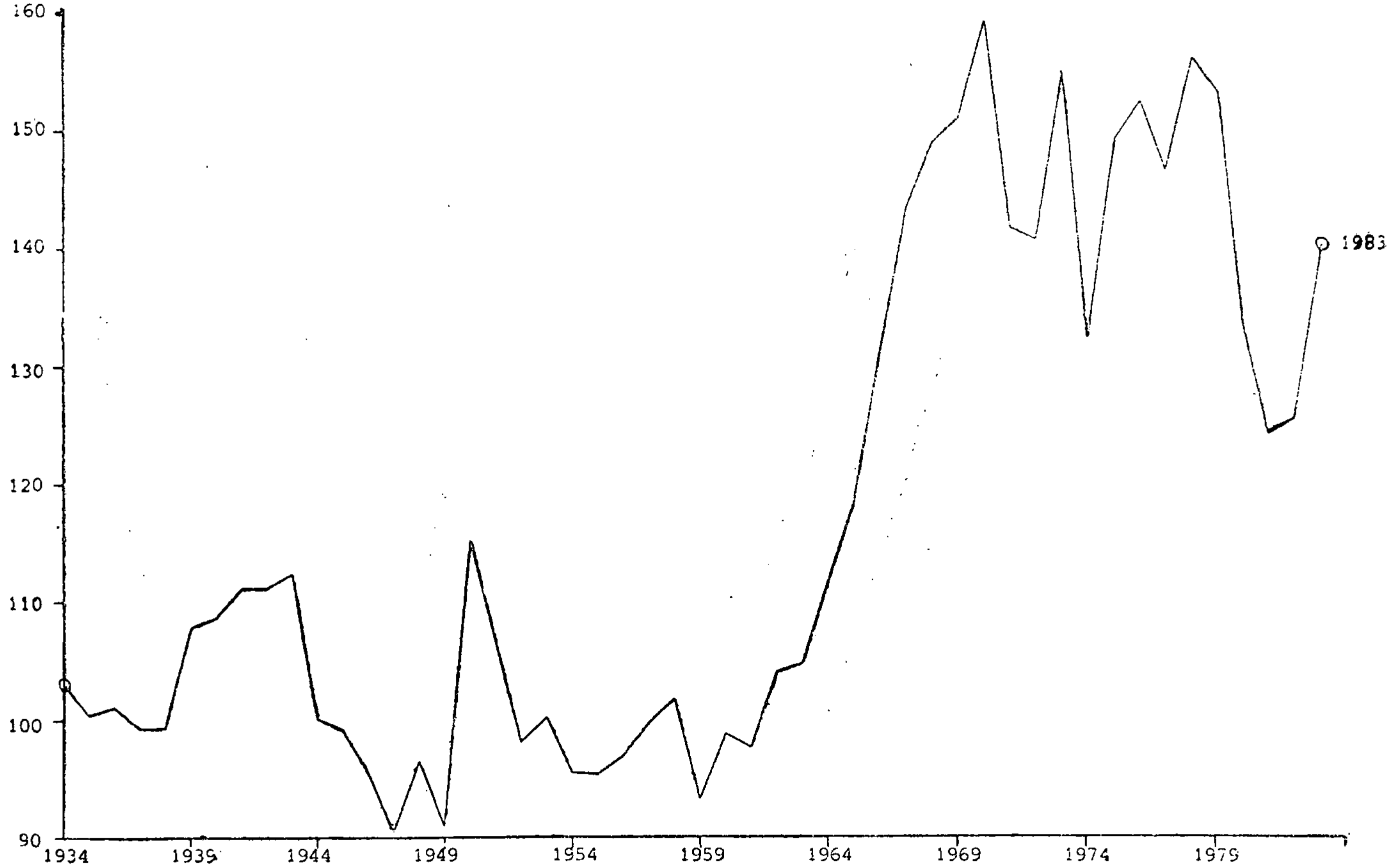

Fig. 1.1. Natural rubber production in Sri Lanka (1000 tonnes) 1934—1983.

Area under rubber has been rather stable, as can be concluded from data from the office of the Rubber Controller of Sri Lanka. In 1945 officially reported area was about 265,000 ha increasing to 270,000 ha in 1960. However, the agricultural census of 1962 revealed that about 42,000 ha of reported rubber land was no longer under rubber. On the one hand rubber land has been neglected and has virtually turned into jungle. On the other hand, there is constant pressure on rubber land from urbanization and infrastructure such as roads. In 1980 there was about 227,000 ha of rubber land of which about three quarters is high-yielding. However, the Department of Census and Statistics reports an area of 194,000 ha in 1980. In accordance with an often practised approach, we define a smallholding with 10 acres or less. The others will be called estates. The estate sector then comprises slightly less than 70 percent of total rubber area.

Replanting and new planting have been marginal in the 1970's, partly due to uncertainties regarding announced land reform programs in 1972 and 1975. In 1953 a government subsidized replanting scheme was started. It was very successful in the beginning, but response dropped dramatically in later stages. In the 1970's the average was slightly over 3,000 ha per year, that is about 1·5 percent of total area and therefore far below 3 percent required to maintain a properly composed rubber area with a maximum age of 33 years which is close to optimal. Replanting reached 5,400 ha in 1980 and is planned to increase substantially in 1985, to some 5 percent of total area, thus compensating for the lack of replanting in the past. After 1986 replanting is aimed at 8,000 ha annually. New planting is very limited *e.g.* replacing uneconomic coconut plantings. The level of new planting in the 1970's was in the order of 200 ha on average per year. Efforts to increase new planting in the 1980's have had some success already with 581 and 977 ha in 1979 and 1980 respectively increasing to 1650 ha in 1982. Plans call for a level of around 900 ha per year in the first half of the 1980's and 200 ha annually in the second half.

Production has increased from around 100,000 tonnes in the fifties and early sixties to around 150,000 tonnes in the seventies. However, production only reached 133,000 tonnes in 1980 and dropped further to around 125,000 tonnes in 1981 and 1982. Next to the low price of NR and unfavourable weather conditions, a major reason behind this development is the decrease in tappable area from about 190,000 ha in 1979 to around 150,000 ha in 1985 if the replanting plans are realized. This means that a level of production of about 150,000 tonnes may continue up to 1987. Afterwards there will be an increase. With some 45 percent of rubber area (to be) replanted in the 1970's and 1980's and the other 55 percent to show a further reduction in yield, one may expect a substantial increase in average yield by the year 2000. How much NR output may be expected in the years ahead and what will be the implications of certain planting policies on NR supply ? These questions will be answered in the following sections.

A vintage approach for production analysis

The need for a vintage approach

Rubber production on a commercial basis, started in Sri Lanka in the beginning of this century. The area increased rapidly until the 1940's and decreased slightly afterwards. In analyzing the relationship between production capacity of NR and area, it is essential to include a few aspects.

(a) Trees have an immaturity period of 5 — 8 years, reaching top levels of productions after a few years of tapping and becoming less productive afterwards.

(b) Improvement in the quality of the trees leads to higher productivity for trees of vintages planted later. A tree planted in 1910 provided less rubber than a tree of the 1930-vintage.

(c) A steep increase in productivity was achieved by the introduction of high-yielding trees from the late 1930's onwards. Total rubber area in the past decades therefore consisted of high-yielding trees and ordinary trees strongly influencing rubber output. This is even more true since the ordinary trees, because of slaughter tapping during World War II, have seen their potential yields reduce drastically.

(d) A further reason for including the year of planting in the analysis of the relationship between production and area, is that replanting has been lagging behind and that replanting schemes have not been effective before 1954 and in most of the late sixties and seventies. The strong increase in production in the 1960's was caused by the drastic replanting in 1950's. In the 1970's production stagnated and declined in 1980 amongst others because of successful replanting efforts.

(e) Because of differences in productivity and planting, estates and smallholdings need to be distinguished.

Planting data for estates and smallholdings

Area data on natural rubber are shown in Table 2.1, columns (1), (2) and (3). Data do not always represent actual rubber area, as was *e.g.* revealed by the 1962 census. Uprooted area may still be registered as rubber area. Between 1945 and 1962 data have been adjusted proportionately in the analysis so as to eliminate a sudden drop in 1962. This has also been done for the data between 1963 and 1983, since the Department of Census and Statistics gives a figure of 194,000 hectares for 1980. Wherever aggregate data or the split-up between estates and smallholdings were not available, linear interpolation has been applied. According to available data (Table 2.1), the smallholder sector comprises 30·5 % of total area in 1975. The Department of Census and Statistics in its recent " Highland crop survey " reports a percentage of 43. For this reason we have gradually increased the share of smallholder area from 1976 onwards. The results are shown in Table 2.2 and Fig. 2.1.

Replanting data (cf. Table 2.1) for 1976 — 1983 have been disaggregated using the division as applicable for 1975. Disaggregated data on new planting are constructed by using the shares, estates and smallholdings had in replanting. The sum of replanting and new planting is the area with new trees. Results are shown in Table 2.3 and Fig. 2.2.

Table 2.1. *Area and planting of natural rubber (ha)*

Year	Area			Replanting			New planting total
	Estates (2)	Small-holdings (2)	total (3)	Estates (1)	Small-holdings (2)	total (3)	
1901	800	—	800				
1911	59,900	15,000	74,900				
1921	126,400	31,600	158,000				
1931	182,700	45,800	228,500				
1941			258,600				
1945			267,220	38	—	38	1,104
1946	205,300	61,600	266,900	666	—	666	613
1947			266,880	858	—	858	183
1948			266,631	592	—	592	119
1949			265,319	890	—	890	233
1950			265,366	1,566	—	1,566	272
1951			265,300	1,388	—	1,388	570
1952			266,036	1,701	—	1,701	553
1953	195,200	71,300	266,500	2,161	188	2,349	349
1954			266,980	5,886	1,589	7,475	619
1955			267,699	7,006	2,271	9,277	502
1956			266,995	7,215	2,742	9,957	174
1957			267,594	7,055	2,758	9,813	1,131
1958			269,259	5,707	2,652	8,359	936
1959	193,200	77,400	270,600	4,354	3,151	7,505	814
1960			270,924	4,334	2,912	7,246	767
1961			271,686	4,760	2,808	7,568	572
1962			229,765	4,440	2,831	7,271	277
1963			230,033	3,955	2,490	6,445	268
1964			230,204	3,502	1,986	5,488	171
1965			230,465	3,107	1,957	5.064	261
1966			230,622	3,134	1,961	5,095	157
1967			230,495	2,748	1,337	4,085	56
1968	160,948	69,581	230,529	3,424	1,734	5,158	237
1969	163,144	67,511	230,655	3,229	1,665	4,894	126
1970			230,259	2,716	1,431	4,147	112
1971			230,038	2,226	1,208	3,434	238
1972			229,636	2,589	952	3,541	180
1973			228,581	2,016	931	2,947	186
1974	158,491	69,688	228,007	1,879	987	2,866	35
1975	158,851	69,625	227,638	2,072	1,160	3,232	155
1976			226,981			2,551	56
1977			226,568			2,617	34
1978			226,328			3,226	380
1979			226,604			4,168	581
1980			227,240			5,436	977
1981			205,609			6,441	710
1982			205,690			6,782	800

Source : Administrative Reports of the Rubber Controller (various issues)
Association of Natural Rubber Producing Countries (1976)
John Keels' Rubber Statistics (various issues)
Rubber Trends, Economic Intelligence Unit (1979)

Table 2.2. *Estimated data on natural rubber area (ha)*

Year	Area of estates	Area of smallholdings	Total area	Year	Area of estates	Area of smallholdings	Total area
1901	800	0	800	1945	203,793	60,547	264,340
1902	6,710	0	6,710	1946	203,425	61,037	264,462
1903	12,620	0	12,620	1947	200,167	61,846	262,013
1904	18,530	0	18,530	1948	196,754	62,571	259,325
1905	24,440	0	24,440	1949	192,606	63,020	255,625
1906	30,350	2,500	32,850	1950	189,484	63,763	253,247
1907	36,260	5,000	41,260	1951	186,307	64,454	250,761
1908	42,170	7,500	49,670	1952	183,710	65,316	249,026
1909	48,080	10,000	58,080	1953	180,937	66,090	247,027
1910	53,990	12,500	66,490	1954	179,394	65,639	245,033
1911	59,900	15,000	74,900	1955	178,005	65,242	243,248
1912	66,550	16,660	83,210	1956	175,672	64,497	240,169
1913	73,200	18,320	91,520	1957	174,198	64,066	238,264
1914	79,850	19,980	99,830	1958	173,403	63,884	237,287
1915	86,500	21,640	108,140	1959	172,381	63,617	235,997
1916	93,150	23,300	116,450	1960	170,038	63,767	233,805
1917	99,800	24,960	124,760	1961	167,955	64,026	231,981
1918	106,450	26,620	133,070	1962	165,578	64,187	229,765
1919	113,100	28,280	141,380	1963	163,555	64,498	228,054
1920	119,750	29,940	149,690	1964	161,449	64,793	226,242
1921	126,400	31,600	158,000	1965	159,391	65,125	224,516
1922	132,030	33,020	165,050	1966	157,245	65,439	222,684
1923	137,660	34,440	172,100	1967	154,894	65,685	220,578
1924	143,290	35,860	179,150	1968	152,639	65,989	218,627
1925	148,920	37,280	186,200	1969	153,318	63,445	216,762
1926	154,550	38,700	193,250	1970	151,112	63,196	214,409
1927	160,180	40,120	200,300	1971	149,035	63,289	212,224
1928	165,810	41,540	207,350	1972	146,853	63,042	209,877
1929	171,440	42,960	214,400	1973	144,274	62,672	206,946
1930	177,070	44,380	221,450	1974	142,019	62,445	204,464
1931	182,700	45,800	228,500	1975	140,565	61,610	202,175
1932	184,207	46,853	231,060	1976	137,750	61,888	199,638
1933	185,713	47,907	233,620	1977	134,181	63,144	197,325
1934	187,220	48,960	236,180	1978	130,763	64,406	195,169
1935	188,727	50,013	238,740	1979	127,682	65,775	193,457
1936	190,233	51,067	241,300	1980	126,100	67,900	194,000
1937	191,740	52,120	243,860	1981	124,160	69,840	194,000
1938	193,247	53,173	246,420	1982	122,220	71,780	194,000
1939	194,753	54,227	248,980	1983	120,280	73,720	194,000
1940	196,260	55,280	251,540				
1941	197,767	56,333	254,100				
1942	199,273	57,387	256,660				
1943	200,780	58,440	259,220				
1944	202,287	59,493	261,780				

Table 2.3. *Planting data on natural rubber (ha)*

Year	Replanting			New planting			New trees	
	Estates	Smallholdings	Total	Estates	Smallholdings	Total	Estates	Smallholdings
1951	1248	140	1388	513	57	570	1761	197
1952	1541	160	1701	501	52	553	2042	212
1953	2161	188	2349	321	28	349	2482	216
1954	5886	1589	7475	487	132	619	6373	1721
1955	7006	2271	9277	379	123	502	7385	2394
1956	7215	2742	9957	126	48	174	7341	2790
1957	7055	2758	9813	813	318	1131	7868	3076
1958	5707	2652	8359	639	297	936	6346	2949
1959	4354	3151	7505	472	342	814	4826	3493
1960	4334	2912	7246	459	308	767	4793	3220
1961	4760	2808	7568	360	212	572	5120	3020
1962	4440	2831	7271	169	108	277	4609	2939
1963	3955	2490	6445	164	104	268	4119	2594
1964	3502	1986	5488	109	62	171	3611	2043
1965	3107	1957	5064	160	101	261	3267	2058
1966	3134	1961	5095	97	60	157	3231	2021
1967	2748	1337	4085	38	18	56	2786	1355
1968	3424	1734	5158	157	80	237	3581	1814
1969	3229	1665	4894	83	43	126	3312	1708
1970	2716	1431	4147	73	39	112	2789	1470
1971	2226	1208	3434	154	84	238	2380	1292
1972	2589	952	3541	132	48	180	2721	1000
1973	2016	931	2947	127	59	186	2143	990
1974	1379	987	2866	23	12	35	1902	999
1975	2072	1160	3232	99	56	155	2171	1216
1976	1635	916	2551	36	20	56	1671	936
1977	1678	939	2617	22	12	34	1700	951
1978	2068	1158	3226	244	136	380	2312	1294
1979	2672	1496	4168	372	209	581	3045	1704
1980	3936	1500	5436	707	270	977	4643	1770
1981	4941	1500	6441	817	248	1065	5758	1748
1982	5282	1500	6782	1285	365	1650	6567	1865
1983	5500	1500	7000	876	214	1000	6286	1714

Discarding systems and vintages

Reasonably adequate data on area distribution by vintages, *i.e.* the number of hectares planted in year t and still existing in year t is not available for a proper period of time which might act as the period of analysis *e.g.* $t = 1951 \ldots, 1983$. Of course these data might be calculated if the distribution in the starting year 1951 was known and if discarding of trees was given by vintage. Unfortunately, neither is available.

The method adopted in this analysis, is to use aggregate data on new planting, replanting and total area, and to derive mathematically formulated discarding systems, which accurately relate discarding of area to new planting and replanting in the past, resulting in a distribution of the area by age. Underlying this analysis is the argument that if one would know in year t what the area per vintage τ is, say at t' and if one would also know which percentage according to a theoretical discarding system would be discarded for each vintage τ depending on the age of the vintage, $t - \tau$, then one could calculate the area per vintage as well as the total discarded area. However, the parameters of the discarding system are not kown. Now turning around the argument : given data on a distribution by vintages in a year, total discarding of area in the following year may act as a criterion to select among theoretical mathematically formulated discarding systems. Afterwards, discards of trees can be allocated to vintages, using the selected discarding

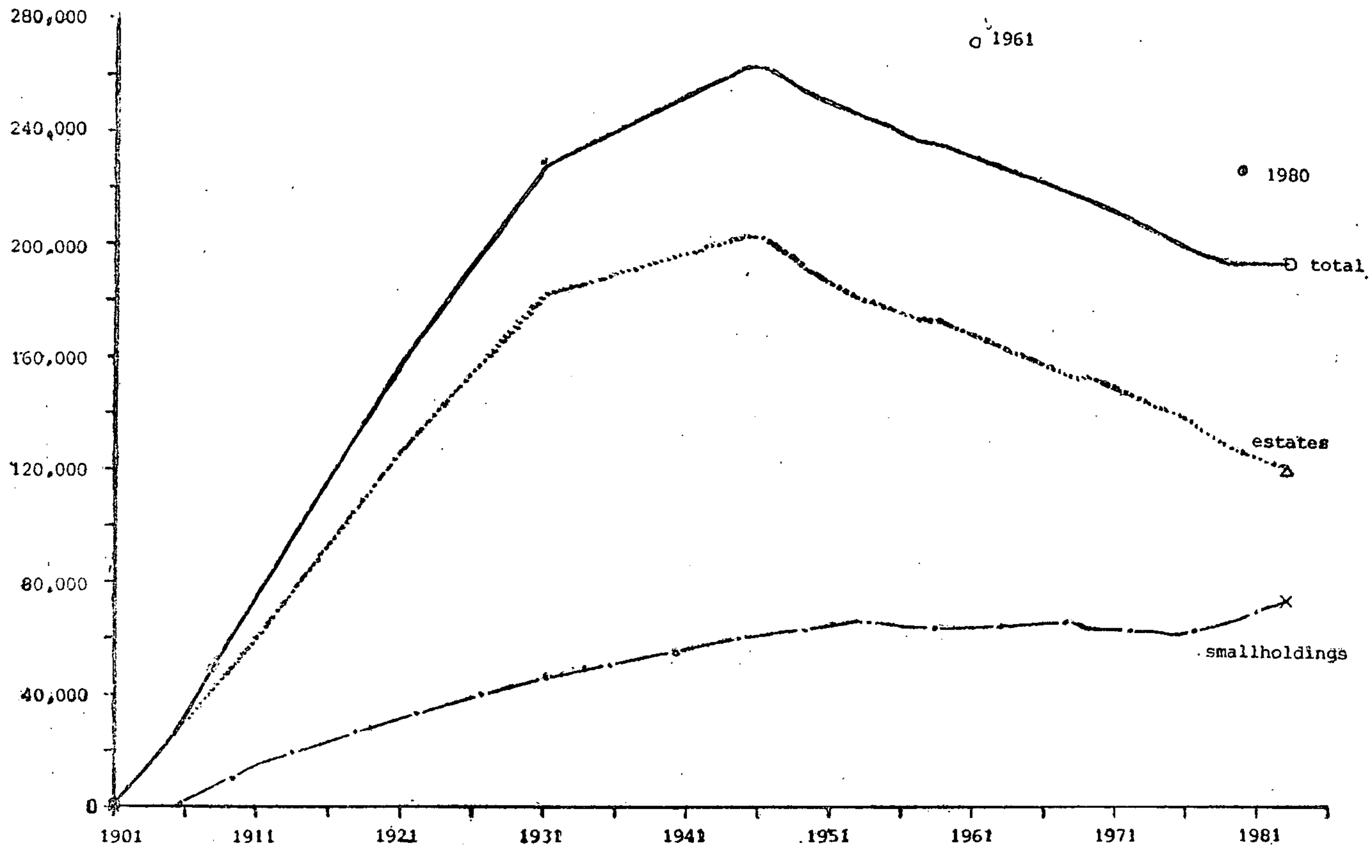

Fig. 2.1. Area under rubber (ha), 1901—1983.

Fig. 2.2. Planting data on natural rubber (ha).

Table 2.4. *Area distribution for estates (ha)*

Year of planting	Year of tapping																												
	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1901	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1902	3	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	7	4	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1904	14	8	5	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1905	26	15	9	6	4	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1906	44	25	14	9	7	4	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1907	68	40	22	15	10	7	4	3	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1908	103	59	34	22	15	10	6	4	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1909	150	87	49	32	23	15	9	6	4	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1910	214	124	70	45	32	21	14	9	6	4	3	2	2	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1911	298	173	98	63	45	29	19	12	9	6	5	3	3	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1912	454	263	149	96	68	44	29	19	13	9	7	5	5	3	2	2	1	0	0	0	0	0	0	0	0	0	0	0	0
1913	608	352	199	129	91	59	38	25	17	13	9	7	4	4	3	2	2	1	0	0	0	0	0	0	0	0	0	0	0
1914	831	481	272	176	125	81	52	34	24	17	13	10	7	5	4	3	3	2	2	0	0	0	0	0	0	0	0	0	0
1915	1173	679	384	248	176	114	74	48	34	24	18	13	10	7	6	5	4	3	2	2	0	0	0	0	0	0	0	0	0
1916	1570	1003	567	367	260	169	109	71	50	36	27	20	15	11	9	7	6	4	3	3	2	0	0	0	0	0	0	0	0
1917	2001	1391	872	564	399	260	168	110	76	55	41	31	23	17	14	11	9	7	5	4	3	3	0	0	0	0	0	0	0
1918	2453	1822	1249	870	616	400	259	169	118	85	63	47	36	26	22	17	13	10	8	6	5	4	3	0	0	0	0	0	0
1919	2916	2283	1677	1248	935	608	393	257	179	129	96	71	54	39	33	25	20	15	12	9	8	6	5	4	0	0	0	0	0
1920	3381	2762	2143	1680	1325	927	600	392	273	197	146	109	83	60	51	39	30	23	18	14	12	9	7	6	4	0	0	0	0
1921	3843	3249	2635	2155	1770	1321	921	601	419	302	224	167	127	92	78	59	47	36	27	22	18	14	11	8	6	5	0	0	0
1922	3780	3287	2763	2339	1986	1561	1162	815	568	409	304	227	172	125	105	80	63	48	37	30	24	19	15	11	8	6	4	0	0
1923	4257	3789	3279	2854	2491	2042	1600	1196	884	637	473	353	268	195	164	125	98	75	58	46	38	30	24	18	13	10	6	3	0
1924	4741	4301	3813	3396	3032	2570	2100	1652	1287	977	726	541	411	299	251	192	151	115	89	71	58	46	36	27	20	15	9	5	2
1925	5216	4808	4347	3946	3589	3128	2644	2168	1761	1402	1092	814	618	449	377	288	227	173	133	106	87	69	55	41	30	22	14	7	3
1926	5732	5353	4921	4538	4191	3737	3248	2753	2315	1915	1555	1214	921	670	563	430	338	259	199	158	130	104	81	62	45	33	21	11	5
1927	6261	5912	5509	5147	4816	4376	3891	3389	2931	2501	2103	1712	1356	986	828	632	497	381	293	233	191	152	120	91	66	48	30	15	7
1928	6830	6509	6135	5795	5480	5057	4582	4082	3614	3162	2735	2303	1897	1451	1219	931	732	560	431	343	282	224	176	133	97	71	44	23	10
1929	7419	7125	6779	6462	6166	5765	5306	4815	4345	3883	3437	2976	2531	2027	1748	1335	1050	804	618	491	404	322	253	191	139	102	64	33	14
1930	7943	7677	7363	7073	6795	6426	5992	5522	5062	4604	4153	3680	3212	2670	2360	1881	1480	1132	871	692	570	454	356	269	196	143	90	46	20
1931	8480	8241	7957	7692	7441	7096	6589	6244	5800	5352	4905	4428	3950	3384	3053	2530	2067	1581	1216	967	796	633	498	376	274	200	125	64	28
1932	3309	3231	3136	3048	2965	2849	2710	2556	2401	2242	2082	1910	1734	1523	1397	1196	1011	807	621	493	406	323	254	192	140	102	64	33	14
1933	3616	3544	3457	3375	3296	3188	3055	2908	2757	2600	2442	2269	2091	1874	1744	1531	1332	1105	886	704	580	461	363	274	200	146	91	47	20
1934	3948	3881	3801	3725	3652	3550	3424	3284	3137	2984	2827	2656	2478	2259	2127	1908	1698	1454	1211	998	821	654	514	388	283	207	129	66	29
1935	4301	4240	4166	4096	4028	3933	3814	3681	3539	3390	3237	3068	2592	2675	2542	2322	2105	1851	1590	1354	1148	914	719	543	396	289	181	93	40
1936	4674	4618	4550	4485	4423	4335	4223	4096	3959	3815	3657	3502	3330	3116	2985	2767	2550	2290	2017	1764	1538	1267	996	752	548	401	251	129	55
1937	5060	5009	4947	4887	4830	4749	4655	4535	4403	4264	4120	3960	3792	3584	3457	3244	3030	2768	2490	2227	1986	1688	1370	1035	754	551	345	177	76
1938	5450	5403	5347	5292	5240	5166	5080	4980	4854	4720	4582	4427	4265	4064	3943	3737	3529	3272	2995	2728	2479	2162	1807	1420	1034	756	473	243	104
1939	5834	5792	5740	5691	5644	5577	5498	5407	5315	5187	5054	4905	4750	4557	4442	4247	4048	3799	3527	3262	3011	2683	2296	1869	1425	1041	652	334	144
1940	6201	6163	6117	6073	6030	5969	5898	5816	5733	5644	5517	5375	5226	5043	4936	4753	4565	4328	4067	3809	3561	3230	2820	2363	1877	1429	895	459	197
1941	6541	6508	6467	6427	6389	6335	6271	6198	6123	6043	5956	5821	5681	5508	5410	5241	5065	4844	4597	4351	4113	3784	3360	2883	2367	1872	1259	645	277
1942	6849	6819	6783	6748	6714	6666	6610	6544	6478	6406	6329	6239	6107	5945	5856	5701	5540	5336	5107	4876	5651	4331	3899	3412	2879	2348	1682	968	416
1943	7117	7090	7059	7028	6998	6956	6906	6849	6790	6726	6658	6579	6490	6340	6259	6120	5974	5789	5579	5366	5157	4852	4418	3930	3391	2837	2137	1356	682
1944	7343	7320	7293	7266	7240	7203	7160	7103	7058	7002	6942	6872	6794	6691	6619	6495	6364	6197	6008	5815	5623	5336	4905	4423	3888	3321	2606	1784	1022
1945	1508	1504	1499	1495	1490	1484	1476	1467	1458	1449	1438	1426	1412	1394	1382	1360	1337	1307	1273	1239	1204	1151	1067	973	868	755	612	445	281
1946	1190	1187	1184	1181	1178	1173	1168	1162	1156	1150	1143	1135	1126	1113	1105	1090	1075	1054	1032	1008	984	946	883	813	735	648	540	412	280
1947	959	957	955	953	951	948	944	940	936	932	927	921	915	907	901	891	880	866	850	834	817	790	741	687	628	560	477	379	274
1948	610	608	607	606	605	603	601	599	597	595	592	589	586	581	578	572	567	559	550	541	532	517	487	455	419	378	328	268	204
1949	990	987	985	983	982	980	977	974	971	968	964	960	956	949	945	937	929	919	907	895	882	859	813	763	709	644	568	477	376
1950	1687	1683	1679	1676	1673	1670	1667	1663	1658	1653	1648	1642	1636	1627	1620	1609	1598	1583	1565	1547	1529	1493	1417	1337	1250	1144	1021	876	712
1951	1751	1747	1744	1740	1738	1735	1731	1728	1724	1720	1715	1710	1704	1696	1691	1681	1671	1657	1642	1626	1610	1576	1500	1421	1335	1229	1109	968	808
1952	2033	2029	2024	2020	2017	2014	2010	2006	2003	1999	1994	1989	1983	1976	1970	1961	1951	1937	1922	1906	1890	1869	1784	1695	1600	1480	1347	1193	1017
1953	2474	2468	2463	2458	2455	2450	2446	2441	2438	2433	2429	2424	2418	2410	2404	2394	2384	2370	2355	2338	2322	2300	2275	2168	2054	1908	1749	1569	1361
1954	6362	6348	6334	6323	6314	6302	6291	6280	6270	6261	6251	6239	6227	6209	6197	6176	6153	6124	6089	6054	6017	5969	5916	5843	5553	5176	4774	4325	3807
1955	7385	7370	7353	7340	7329	7316	7303	7290	7279	7268	7259	7248	7235	7218	7206	7185	7163	6134	7100	7065	7029	6982	6930	6857	6762	6322	5861	5355	4772
1956	0	7341	7325	7312	7301	7288	7275	7262	7251	7241	7231	7222	7211	7197	7187	7169	7151	7126	7098	7068	7038	6998	6954	6893	6812	6723	6261	5761	5185
1957	0	0	7868	7854	7843	7829	7815	7801	7789	7778	7768	7758	7748	7735	7726	7710	7693	7671	7645	7618	7591	7555	7514	7458	7385	7303	7162	6629	6018
1958	0	0	0	6346	6337	6326	6314	6303	6294	6285	6277	6269	6261	6252	6246	6235	6223	6208	6191	6172	6153	6129	6101	6063	6012	5956	5859	5705	5216
1959	0	0	0	0	4826	4818	4809	4801	4794	4787	4781	4775	4769	4762	4758	4751	4744	4734	4723	4711	4699	4683	4665	4640	4607	4571	4508	4408	4272
1960	0	0	0	0	0	4793	4784	4776	4769	4762	4756	4750	4744	4738	4734	4728	4721	4713	4704	4694	4684	4670	4655	4634	4607	4576	4523	4439	4323
1961	0	0	0	0	0	0	5120	5111	5103	5096	5090	5083	5077	5070	5066	5059	5054	5046	5038	5029	5020	5008	4994	4975	4950	4923	4874	4797	4692
1962	0	0	0	0	0	0	0	4609	4602	4596	4590	4584	4579	4572	4569	4563	4558	4552	4546	4539	4532	1523	4512	4498	4479	4458	4421	4362	4281
1963	0	0	0	0	0	0	0	0	4119	4114	4109	4103	4098	4093	4089	4084	4080	4075	4070	4065	4060	4053	4045	4034	4020	4004	3976	3931	3869
1964	0	0	0	0	0	0	0	0	0	3611	3607	3602	3598	3593	3590	3586	3582	3577	3573	3569	3565	3560	3554	3546	3535	3524	3503	3470	3424
1965	0	0	0	0	0	0	0	0	0	0	3267	3263	3259	3255	3252	3248	3245	3241	3237	3233	3230	3226	3222	3216	3208	3199	3183	3157	3122
1966	0	0	0	0	0	0	0	0	0	0	0	3231	3227	3222	3220	3216	3212	3209	3205	3201	3198	3195	3191	3186	3179	3172	3158	3137	3108
1967	0	0	0	0	0	0	0	0	0	0	0	0	2786	2782	2780	2776	2773	2770	2767	2764	2761	2758	2756	2752	2747	2742	2732	2716	2695
1968	0	0	0	0	0	0	0	0	0	0	0	0	0	3581	3578	3574	3570	3566	3562	3558	3555	3551	3548	3544	3538	3532	3522	3505	3481
1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3908	3903	3899	3894	3890	3886	3882	3873	3875	3870	3865	3860	3850	3834	3813
1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2789	2786	2783	2780	2777	2774	2772	2769	2766	2762	2759	2753	2744	2731
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2380	2377	2375	2372	2370	2368	2365	2363	2360	2357	2353	2346	2337
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2721	2717	2715	2712	2710	2707	2704	2700	2697	2692	2686	2677
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2143	2141	2139	2137	2135	2133	2130	2127	2124	2118	2112
1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1902	1900	1898	1897	1894	1892	1890	1887	1882	1877
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2171	2169	2167	2165	2162	2160	2156	2151	2145
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1671	1670	1668	1666	1664	1661	1657	1652
1977	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1700	1698	1696	1694	1691	1687	1682
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	2312	2309	2306	2302	2297	2290
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	3045	3041	3036	3029	3020
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	4643	4635	4625	4612
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5758	5745	5729
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6567	6549
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	6286

Table 2.5. *Area distribution smallholdings (ha)*

Year of tapping

Year of planting	1955	1956	1957	1958	1959	1960	1961	1962	1963	1964	1965	1966	1967	1968	1969
1901	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1902	1	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	2	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1904	4	3	2	1	1	1	0	0	0	0	0	0	0	0	0
1905	8	6	4	3	2	1	1	0	0	0	0	0	0	0	0
1906	284	196	131	89	52	33	20	12	7	5	3	0	0	0	0
1907	368	254	169	115	68	42	26	15	9	6	4	3	0	0	0
1908	461	318	213	144	85	53	33	19	12	8	5	4	3	0	0
1909	564	389	260	176	104	65	40	24	15	10	7	4	3	2	0
1910	694	478	319	217	128	80	49	29	18	12	8	5	4	3	1
1911	364	397	399	271	159	100	62	36	22	15	10	7	5	4	1
1912	758	556	372	252	149	93	58	34	21	14	10	6	5	4	1
1913	897	691	494	336	198	124	77	45	28	19	13	9	7	5	2
1914	1037	832	628	455	268	168	104	61	38	25	17	12	9	6	2
1915	1175	975	770	587	380	238	147	87	53	36	24	16	13	9	3
1916	1310	1118	915	728	507	344	213	126	77	52	35	24	18	13	5
1917	1440	1259	1062	875	646	467	315	186	114	77	52	35	27	20	7
1918	1565	1396	1208	1025	794	605	435	283	174	117	79	54	41	30	10
1919	1686	1528	1351	1175	948	753	572	399	267	180	122	83	64	46	16
1920	1802	1657	1492	1324	1104	909	721	534	382	276	187	126	98	70	24
1921	1914	1782	1629	1472	1261	1069	879	684	517	393	285	192	149	107	37
1922	1712	1611	1492	1368	1199	1042	884	715	566	450	344	248	192	139	48
1923	1725	1637	1533	1423	1272	1129	982	822	676	559	446	340	274	198	68
1924	1740	1664	1573	1476	1341	1211	1077	927	788	672	557	444	370	282	97
1925	1778	1711	1630	1544	1422	1304	1182	1042	910	797	681	564	485	386	168
1926	1787	1729	1658	1583	1476	1370	1261	1135	1015	910	799	682	602	497	256
1927	1801	1751	1690	1623	1529	1434	1339	1226	1118	1023	919	807	727	619	361
1928	1797	1753	1701	1643	1561	1478	1396	1297	1204	1121	1027	923	847	742	475
1929	1796	1759	1713	1663	1592	1519	1449	1364	1286	1215	1132	1039	969	868	600
1930	1885	1851	1810	1764	1699	1632	1570	1493	1425	1363	1288	1200	1135	1037	761
1931	1980	1949	1912	1871	1811	1749	1695	1627	1568	1515	1449	1369	1309	1216	937
1932	1364	1346	1324	1299	1264	1227	1191	1146	1105	1067	1021	969	928	868	697
1933	1423	1407	1387	1364	1332	1299	1267	1228	1193	1160	1121	1074	1038	982	815
1934	1487	1472	1454	1434	1405	1375	1348	1313	1284	1257	1224	1183	1151	1101	940
1935	1557	1544	1528	1510	1483	1456	1433	1403	1380	1359	1331	1296	1269	1224	1070
1936	1635	1623	1608	1592	1568	1543	1524	1498	1481	1465	1443	1414	1393	1353	1206
1937	1719	1708	1695	1680	1658	1636	1609	1588	1576	1567	1550	1528	1512	1478	1341
1938	1811	1881	1789	1776	1756	1735	1711	1681	1675	1671	1660	1645	1633	1606	1477
1939	1910	1901	1890	1877	1859	1840	1818	1791	1761	1763	1759	1749	1744	1723	1604
1940	2014	2006	1996	1985	1969	1951	1931	1906	1875	1852	1854	1851	1851	1836	1727
1941	2124	2116	2107	2097	2082	2066	2048	2025	2000	1976	1949	1952	1957	1948	1849
1942	2236	2230	2221	2212	2199	2184	2167	2147	2124	2102	2077	2047	2057	2055	1964
1943	2349	2343	2336	2327	2315	2302	2287	2268	2247	2227	2204	2177	2156	2159	2077
1944	2459	2454	2447	2440	2429	2417	2403	2386	2367	2349	2328	2304	2285	2257	2183
1945	1069	1067	1065	1062	1058	1053	1048	1042	1035	1028	1020	1011	1004	993	965
1946	77	76	76	76	76	76	75	75	74	74	74	73	72	72	70
1947	73	72	72	72	72	72	71	71	71	70	70	70	69	69	67
1948	96	96	95	95	95	95	95	94	94	93	93	92	92	91	90
1949	126	125	125	125	125	125	124	124	123	123	122	122	121	121	119
1950	140	140	140	140	139	139	139	138	138	138	137	137	136	135	134
1951	197	197	196	196	196	195	195	914	194	193	193	192	191	191	188
1952	212	211	211	210	210	210	209	209	208	208	207	207	206	205	203
1953	215	215	215	214	214	214	213	213	212	212	211	211	210	210	208
1954	1719	1716	1713	1710	1707	1703	1700	1696	1693	1690	1687	1683	1680	1675	1663
1955	2394	2390	2386	2382	2377	2373	2368	2363	2358	2354	2350	2346	2342	2336	2322
1956	0	2790	2785	2781	2775	2770	2764	2759	2753	2748	2744	2739	2735	2730	2715
1957	0	0	3076	3071	3065	3059	3053	3046	3040	3035	3030	3025	3021	3016	3002
1958	0	0	0	2949	2943	2937	2932	2926	2920	2915	2910	2905	2902	2897	2886
1959	0	0	0	0	3493	3486	3480	3472	3465	3460	3454	3448	3444	3439	3427
1960	0	0	0	0	0	3220	3214	3207	3201	3196	3191	3185	3181	3177	3166
1961	0	0	0	0	0	0	3020	3014	3008	3003	2998	2993	2990	2985	2975
1962	0	0	0	0	0	0	0	2939	2933	2928	2923	2919	2915	2911	2901
1963	0	0	0	0	0	0	0	0	2594	2589	2585	2581	2578	2574	2565
1964	0	0	0	0	0	0	0	0	0	2048	2045	2041	2039	2036	2029
1965	0	0	0	0	0	0	0	0	0	0	2058	2054	2052	2049	2042
1966	0	0	0	0	0	0	0	0	0	0	0	2021	2019	2016	2010
1967	0	0	0	0	0	0	0	0	0	0	0	0	1355	1353	1349
1968	0	0	0	0	0	0	0	0	0	0	0	0	0	1814	1808
1969	0	0	0	0	0	0	0	0	0	0	0	0	0	0	1708
1970	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1971	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1972	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1973	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1974	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1975	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1976	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1977	0	0	0	0	0	0	0	0	0	0	p	0	0	0	0
1978	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1979	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1980	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1981	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1982	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Year of planting	1970	1971	1972	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983
1901	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1902	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1903	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1904	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1905	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1906	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1907	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1908	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1909	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1910	0	0	0	0	0	0	0	0	0	0	0	0	0	0
1911	1	0	0	0	0	0	0	0	0	0	0	0	0	0
1912	1	1	0	0	0	0	0	0	0	0	0	0	0	0
1913	1	1	1	0	0	0	0	0	0	0	0	0	0	0
1914	2	1	1	1	0	0	0	0	0	0	0	0	0	0
1915	2	2	1	1	1	0	0	0	0	0	0	0	0	0
1916	3	2	2	1	1	1	0	0	0	0	0	0	0	0
1917	5	3	3	2	2	1	1	0	0	0	0	0	0	0
1918	7	5	4	3	3	2	1	1	0	0	0	0	0	0
1919	11	8	6	5	4	3	2	2	2	0	0	0	0	0
1920	17	12	10	7	6	4	3	3	3	2	0	0	0	0
1921	26	19	15	11	9	6	5	5	4	3	3	0	0	0
1922	33	24	19	15	12	8	7	6	5	5	4	3	0	0
1923	47	35	21	21	17	11	9	9	8	7	6	5	4	0
1924	67	50	39	30	24	16	13	13	11	10	9	7	6	6
1925	117	86	68	52	41	27	23	21	19	16	14	12	11	9
1926	188	139	109	84	66	44	37	34	30	26	22	19	17	14
1927	279	216	170	130	103	68	58	53	47	39	34	30	25	22
1928	382	308	252	193	153	101	86	78	69	58	51	44	38	32
1929	499	416	350	280	221	147	124	113	100	84	73	63	54	46
1930	651	557	482	398	327	217	184	166	146	123	107	92	79	68
1931	820	719	635	540	457	324	275	248	217	182	157	136	116	99
1932	622	556	500	436	378	284	245	214	183	151	127	107	91	77
1933	740	672	614	546	484	380	336	302	258	212	179	152	129	109
1934	865	797	738	667	602	491	443	408	359	296	250	212	179	153
1935	997	929	870	798	731	615	565	532	481	410	347	294	249	212
1936	1135	1069	1010	939	870	751	702	674	624	549	479	406	345	293
1937	1273	1209	1151	1081	1014	894	846	829	785	709	637	556	472	402
1938	1413	1352	1297	1229	1162	1045	1000	997	963	891	822	737	643	547
1939	1544	1486	1434	1370	1306	1192	1153	1167	1148	1086	1027	943	842	735
1940	1672	1618	1569	1508	1448	1339	1307	1341	1339	1293	1251	1173	1070	956
1941	1797	1748	1702	1645	1589	1486	1461	1516	1534	1507	1488	1425	1325	1207
1942	1917	1872	1830	1777	1725	1629	1611	1687	1727	1721	1730	1688	1600	1484
1943	2034	1993	1954	1906	1858	1769	1758	1857	1918	1934	1973	1955	1886	1782
1944	2145	2107	2072	2028	1983	1902	1899	2018	2101	2140	2210	2220	2174	2089
1945	951	936	923	906	889	857	849	866	874	870	873	863	840	809
1946	69	68	67	66	65	63	70	99	124	146	175	194	205	210
1947	66	66	65	64	63	62	67	91	113	132	157	175	186	194
1948	89	88	87	86	85	83	86	102	115	127	144	156	163	168
1949	118	117	116	115	114	111	117	144	167	189	218	241	256	269
1950	133	132	131	130	129	126	137	185	228	267	322	366	398	426
1951	187	186	185	184	182	180	191	241	287	329	388	435	472	504
1952	202	201	200	199	198	195	194	254	309	361	434	493	540	584
1953	207	206	205	204	203	201	199	198	270	339	436	516	581	644
1954	1656	1650	1644	1636	1628	1613	1604	1595	1583	1760	2016	2226	2399	2570
1955	2314	2306	2299	2289	2280	2262	2251	2240	2225	2206	2520	2782	3002	3221
1956	2707	2699	2692	2682	2673	2654	2641	2632	2617	2598	2576	2861	3103	3348
1957	2995	2987	2980	2971	2962	2944	2934	2923	2909	2890	2870	2848	3134	3428
1958	2879	2873	2867	2860	2852	2838	2830	2820	2809	2793	2776	2758	2738	2997
1959	3421	3414	3408	3401	3393	3378	3370	3360	3348	3332	3315	3296	3276	3253
1960	3161	3156	3151	3145	3139	3127	3120	3113	3103	3090	3076	3061	3045	3027
1961	2970	2966	2962	2958	2952	2943	2937	2931	2924	2913	2902	2890	2877	2862
1962	2897	2893	2889	2885	2881	2873	2868	2863	2857	2848	2838	2828	2817	2805
1963	2561	2558	2555	2552	2549	2543	2539	2535	2530	2523	2516	2508	2500	2491
1964	2026	2023	2021	2018	2016	2012	2010	2007	2004	1999	1994	1989	1983	1977
1965	2039	2036	2034	2032	2029	2026	2024	2022	2019	2015	2010	2006	2001	1995
1966	2006	2004	2002	1999	1997	1993	1992	1990	1987	1984	1980	1976	1972	1967
1967	1347	1345	1344	1342	1341	1338	1337	1336	1334	1333	1330	1328	1326	1323
1968	1805	1803	1801	1798	1797	1793	1792	1790	1789	1786	1784	1781	1779	1775
1969	1705	1703	1701	1699	1697	1694	1693	1691	1690	1688	1686	1684	1682	1679
1970	1470	1468	1466	1464	1463	1460	1459	1458	1457	1455	1454	1452	1450	1448
1971	0	1292	1290	1289	1287	1285	1284	1283	1282	1281	1279	1278	1277	1275
1972	0	0	1000	999	998	996	996	995	994	993	992	991	990	989
1973	0	0	0	990	989	987	986	985	985	983	982	982	981	980
1974	0	0	0	0	999	997	997	996	995	994	993	992	991	990
1975	0	0	0	0	0	1216	1215	1214	1213	1211	1210	1209	1208	1207
1976	0	0	0	0	0	0	936	935	934	933	932	931	931	930
1977	0	0	0	0	0	0	0	951	951	950	949	948	947	946
1978	0	0	0	0	0	0	0	0	1294	1293	1292	1290	1289	1288
1979	0	0	0	0	0	0	0	0	0	1704	1703	1701	1700	1699
1980	0	0	0	0	0	0	0	0	0	0	1770	1768	1767	1765
1981	0	0	0	0	0	0	0	0	0	0	0	1748	1747	1745
1982	0	0	0	0	0	0	0	0	0	0	0	0	1865	1863
1983	0	0	0	0	0	0	0	0	0	0	0	0	0	1714

system, and the distribution by vintages can be developed year by year. Thus, for each year, theoretical discarding by vintage is adjusted to take care of *e.g.* diseases or high levels of replanting : this is the basis for discarding for the following year.

The above analysis requires a vintage distribution in the starting year, say 1951. Using data on planting in the years up to 1955 as well as a number of feasible mathematically formulated discarding systems, one may derive a number of feasible vintage distributions in the starting year. That discarding system and the corresponding starting year vintage distribution may now be selected, which provides an optimal fit to data on discarding for the sample period, from the starting year onwards.

A graphical presentation of a possible discarding system is shown in Fig. 2.3.

An elaborate description of possible discarding systems and the selection of the optimal one can be found in Smit (1984).

For Sri Lanka a good system appeared to be a linear decrease with 5% for the first 10 years and an exponential decrease afterwards with exponent 0·17% age of the trees for estates and 0·15% age of the trees for smallholdings. The resulting area distributions for estates and smallholdings are given in Tables 2.4 and 2.5.

A supply function for natural rubber

Basic elements of a supply function

The basis for a supply function is a production function. This production function relates production to :

— area, disaggregated into vintages

— yield profiles, so that each vintage can be multiplied with the normal yield of a vintage of planting year T in tapping year t

— technical progress factors shifting yield profiles upwards for later planted, more productive vintages

— flexible inputs such as manpower

— exogenous variables like the weather condition

— the status of the trees in view of tapping in the past : more or less than normal tapping will have adverse effects on later years ; if *e.g.* in year t slaughter tapping is applied, then this may slightly reduce the yield in year t + 1 and strongly in year t + 4 in view of bark consumption and renewal. Slaughter tapping during a number of consecutive years will dramatically reduce the yield of the tree for the rest of its life (cf. World War II).

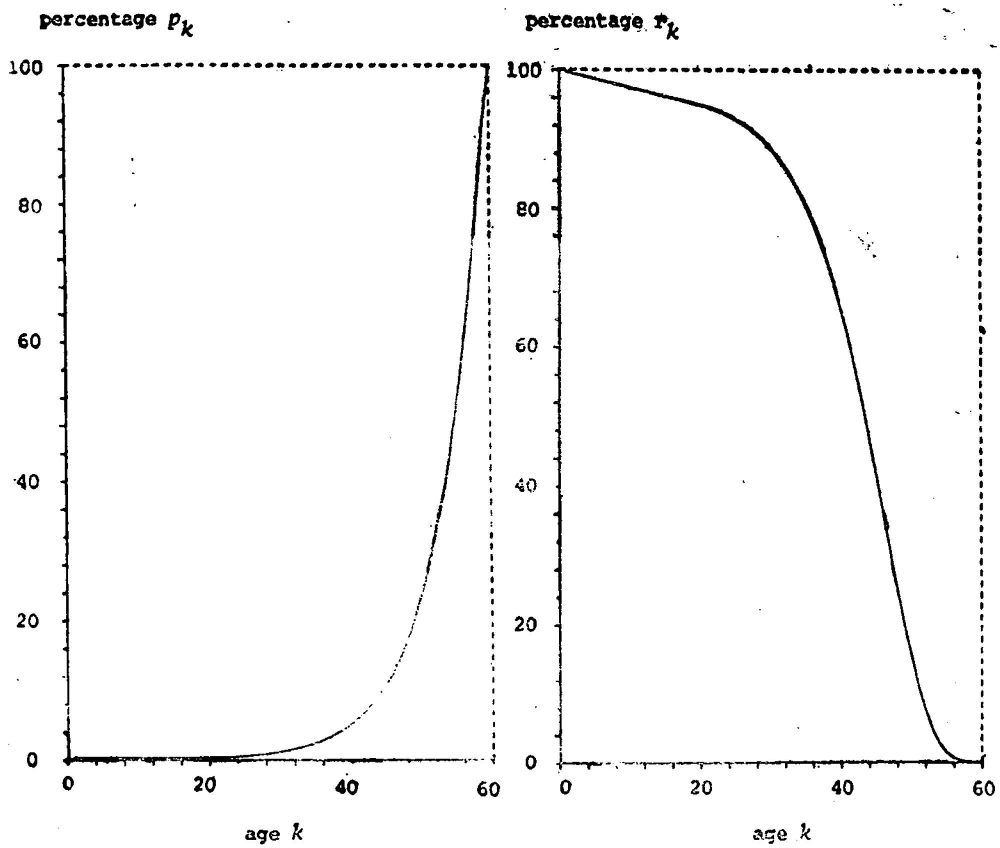

Fig. 2.3. Percentage of remaining area, discarded in year k (p) and percentage of original area remaining after k years (r_k) with a constant reduction in r_k to 95% after 20 years.

The factor to be determined by the rubber producer is the level of flexible inputs. This will depend on the market situation. Classic approaches argue, that profit maximization is the key determining factor. This leads to the inclusion of price elements in the supply function to be derived from the production function on the basis of profit maximization, while flexible inputs, on which no data are available, can be eliminated.

The production function

Yield profiles : Vintages have been discussed in the previous section. In order to arrive at the yield for each vintage in the year of tapping the vintage needs to be multiplied by the average yield appropriate for the age of the vintage. The study on "The Agro-Economic Norm for Natural Rubber" by the Association of Natural Rubber Producing Countries (1976) contains a chapter on Sri Lanka. From this chapter an ideal yield profile is derived as presented in Table 3.1 and Fig. 3.1.

Table 3.1. *Ideal yield profile (kgs per ha)*

Year of tapping	Yield	Year of tapping	Yield
1	420	29	900
2	730	30	850
3	920	31	800
4	1,090	32	750
5	1,180	33	700
6	1,230	34	650
7	1,290	35	600
8	1,350	36	550
9	1,400	37	500
10	1,400	38	450
11	1,400	39	400
12	1,400	40	350
13	1,400	41	300
14	1,400	42	280
15	1,350	43	260
16	1,350	44	240
17	1,350	45	220
18	1,350	46	200
19	1,350	47	180
20	1,230	48	160
21	1,230	49	140
22	1,230	50	120
23	1,230	51	100
24	1,170	52	80
25	1,100	53	60
26	1,050	54	40
27	1,000	55	20
28	950	56	0

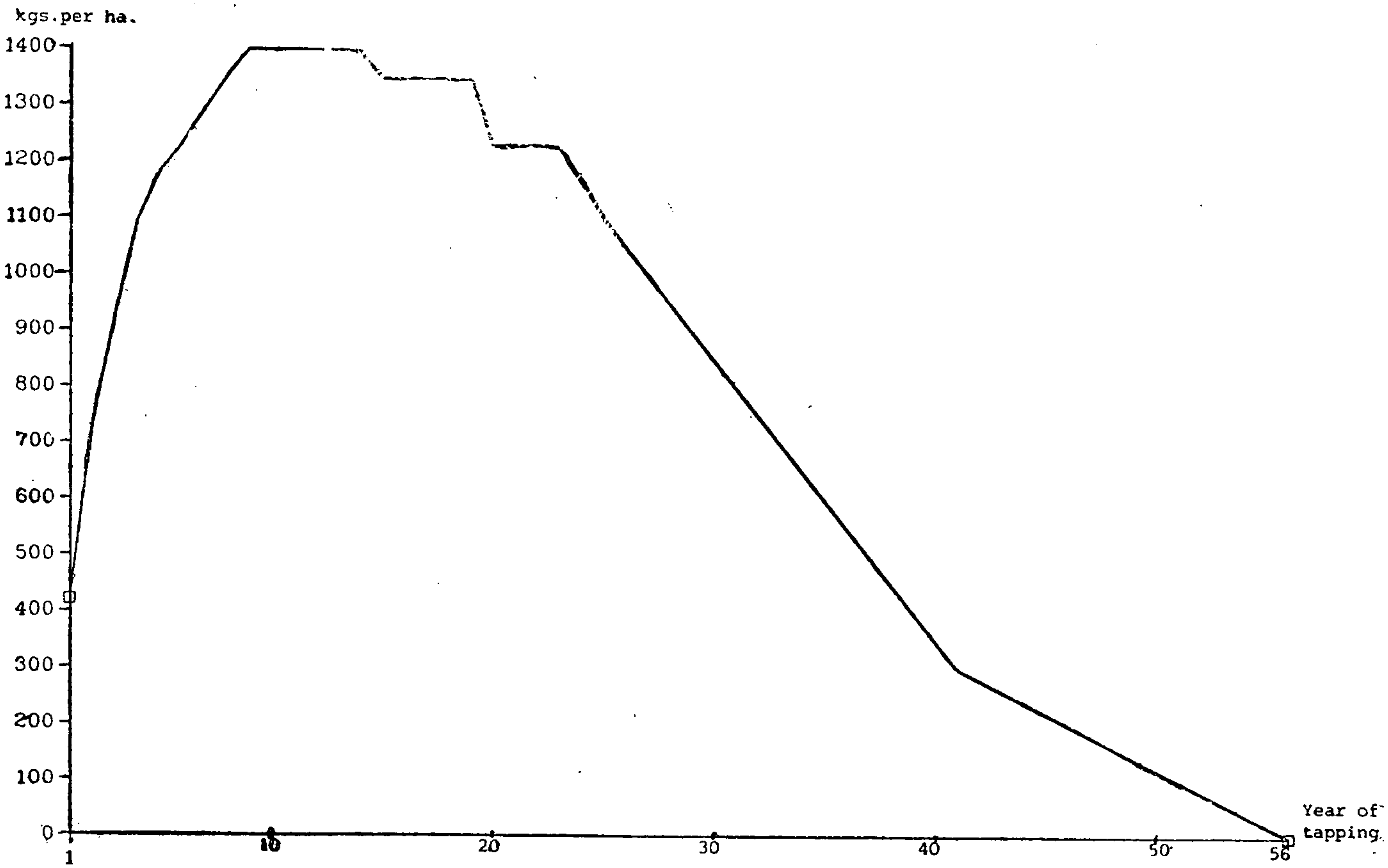

Fig. 3.1. Ideal yield profile.

Partly, the yield profiles have been derived by straightforward extrapolation in order to complete the picture for very old trees. These yields are obtained under experimental conditions. In commercial practice, yields will be somewhat lower, although the shape of the yield profile may still be valid. The ideal yield profile therefore needs to be multiplied with a certain factor, in order to reduce the ideal yield profile to actual levels. This multiplication factor will be different for different countries, and, within countries, for estates and smallholdings. A reason may be the selection of clones. This selection of clones of which a certain vintage is composed may vary over time, implying that the multiplication factor may need to increase over time in view of technical progress.

The assumption now is that each vintage will have an average yield profile, which is a constant fraction of the ideal yield profile : if a yield profile is estimated to be for example 0·5 times the ideal yield profile, then the profile is suppressed to 50 percent of the original shape with a value of 365 kg per ha in the second year of tapping. Of course, later vintages may be composed of better clones, thus increasing average yield. In the example, the fraction of 0·5 may become 0·6 after a number of years. The fractions are estimated per vintage in the following sub-section, by relating area and ideal yield profile to production and then deriving the fractions which create actual yield profiles that are consistent with area composition and production. As a matter of clarification, it is derived that trees planted *e.g.* in 1950 on estates have a yield profile which is about 75 percent of the ideal yield profile. This vintage, of course, will only reach high production levels around 1962.

Technical progress : There are a number of factors which have contributed to the increase in productivity of rubber land. By far the most important one is the improvement of the quality of trees. This partly needs to be combined with the application of fertilizers and possibly stimulants. All this may be put under the collective name " embodied technical progress ". There is another group of factors improving yield of rubber land which may be called " disembodied technical progress ". To this group belong such aspects as improved tapping methods. Embodied technical progress, embodied in the quality of the trees and thus in the vintages is by far the most important group. It has therefore been decided to emphasize the inclusion of embodied technical progress in the analysis, which then can be specified as a function of the vintage, the year of planting.

The production function may therefore be specified as :

$$q^*_t = \sum_{k=1}^{2} f^k(\tau)\, y_{t-\tau}\, a^k_{t\tau} \qquad (3.1)$$

with q^*_t = production capacity of NR in Sri Lanka

$k = 1$ = estates

$k = 2$ = smallholdings

τ = year of planting

t = year of tapping

$f^k(\tau)$ = embodied technical progress function

$Y_{t-\tau}$ = ideal yield profile, age = $t - \tau$

$a^k_{t\tau}$ = area of vintage τ still remaining in year t

The ideal yield profile is adjusted for the length of the immaturity period, which may vary around 6 years. There are many possible specifications for $f^k(\tau)$. In this study only linear functions are applied.

In view of the lack of data on production capacity or "normal production" and on flexible input, it has not been attempted to estimate this production function. Below the supply function, including prices, will be estimated directly. Then factors like weather conditions and slaughter tapping will be investigated as well.

The supply function

Moving from the production function to the supply function, special attention needs to be paid to those factors determining the degree of capacity utilization $u^c{}_t$

$$q_t = u^c{}_t \cdot q^*{}_t \qquad (3.2)$$

with q_t = production

$^*q_t$ = production capacity or "normal production"

Above a number of factors determining u_t has already been mentioned :

$f(P)$ = function of prices

$f(E^c)$ = the influence of the rubber-rice-barter with China until 1982

$f(R)$ = rainfall

$f((q/q^*)_{t-1})$ = "abnormal" tapping in the past

The supply function is now broadly specified

$$q_t = f(P) \cdot f(E^c) \cdot f(R) \cdot f\ (q/q^*)_{t-1}) \sum_{k=1}^{2} f^k(\tau)\, Y_{t-\tau} a^k{}_t T \qquad (3.3)$$

Presentation of the numerous detailed specification and estimation results would require many uninteresting pages. Only the optimal results are given below. An iterative procedure has been used to estimate the parameters. Note that in view of the number of parameters it has not been possible to obtain parameters for the factors influencing $u^c{}_t$ separately for estates and smallholdings. Technical progress functions, however, have been estimated separately for estates and smallholdings. The resulting value for every tenth year is shown in Table 3.2.

Table 3.2. *Estimated values of embodied technical progress functions (equation (3.3))*

Year	Estates	Smallholdings
1910	0·165	0·149
1920	0·168	0·152
1930	0·171	0·155
1940	0·646	0·592
1950	0·673	0·620
1960	0·701	0·647
1970	0·728	0·675
1980	1·414	1·317
1990	1·469	1·372
2000	1·525	1·427

These technical progress functions, together with the "ideal" yield profile and the area distribution determines "normal" production as given in equation (3.1). The parameters of the technical progress functions are estimated simultaneously with the parameters of the functions determining u^{c}_{t}. The year 1970, being rather exceptional, has been excluded. The results are :

$$q_t = 1{\cdot}0937(P_t^{+})^{0{\cdot}1994} \cdot (P_t^{-})^{-0{\cdot}4525} \cdot (E^{c}_t)^{0{\cdot}1413} \cdot (R_t^{-})^{0{\cdot}5893} \cdot \left(\frac{q_{t-4}}{q^{*}_{t-4}}\right)^{-0{\cdot}4114} \cdot q^{*}_t \qquad (3.4)$$

$$R^2 = 0{\cdot}984$$

with $P_t^{+} = P_t/P_{t-1}$ if $P_t > P_{t-1}$

$= 1$ otherwise

$P^{-}_t = P_t/P_{t-1}$ if $P_t < P_{t-1}$

$= 1$ otherwise

$E^{c}_t = (1 + E_t^{China}/E_t)$

E_t^{China} = exports of rubber to China, effective until 1982

E_t = exports of rubber

R^{-}_t = actual rainfall divided by normal rainfall, of less than normal

$= 1$ otherwise.

The theoretical background of the specification of the above equation is based on assumptions of consumer and producer theory, in particular that in a period of declining prices, producers may need to produce more, if they have no alternative sources of income, in order to keep their consumption at an adequate level. The observed and the estimated values are shown in Table 3.3 and Fig. 3.2

Table 3.3. *Observed values and estimated values (equation (3.4) of rubber production (1000 tonnes)*

Year	Observed production	Estimated production
1955	95·3	93·3
1956	96·9	97·5
1957	99·7	101·6
1958	101·8	95·4
1959	93·2	93·6

Table 3.3 *(Continued)*

Year	Observed production	Estimated production
1960	98·8	97·9
1961	97·6	101·9
1962	104·1	100·7
1963	104·8	108·1
1964	111·6	114·9
1965	118·3	123·2
1966	131·0	130·3
1967	143·2	143·2
1968	148·7	144·4
1969	150·8	147·0
1970	159·2	150·4
1971	141·4	143·5
1972	140·4	139·3
1973	154·7	152·9
1974	132·0	135·3
1975	148·8	149·8
1976	152·1	153·2
1977	146·2	144·6
1978	155·7	159·3
1979	152·7	150·3
1980	133·2	135·7
1981	123·9	123·5
1982	125·2	121·9
1983	139·9	139·1

It has not been possible to estimate standard errors for the parameters. An approximation can be found by using " normal capacity " q^*_t as estimated above and by transforming (3.4) into natural logarithms. Estimation results with t - values in brackets are :

$$\ln q_t = 0{\cdot}2521 + \underset{(27{\cdot}402)}{0{\cdot}9864} \ln q^*_t + \underset{(4{\cdot}241)}{0{\cdot}2030} \ln P^+_t - \underset{(4{\cdot}651)}{0{\cdot}4339} \ln P^-_t +$$

$$+ \underset{(1{\cdot}984)}{0{\cdot}1329} \ln E^c_t + \underset{(6{\cdot}252)}{0{\cdot}5666} \ln R^-_t - \underset{(3{\cdot}853)}{0{\cdot}4278} \ln \frac{q_{t-4}}{q^*_{t-4}} \tag{3.5}$$

$$R^2 = 0{\cdot}982, \quad DW = 2{\cdot}38$$

While the coefficient of $\ln E^c_t$ is almost significant, all other coefficients are significant and all are very close to the results of equation (3.4).

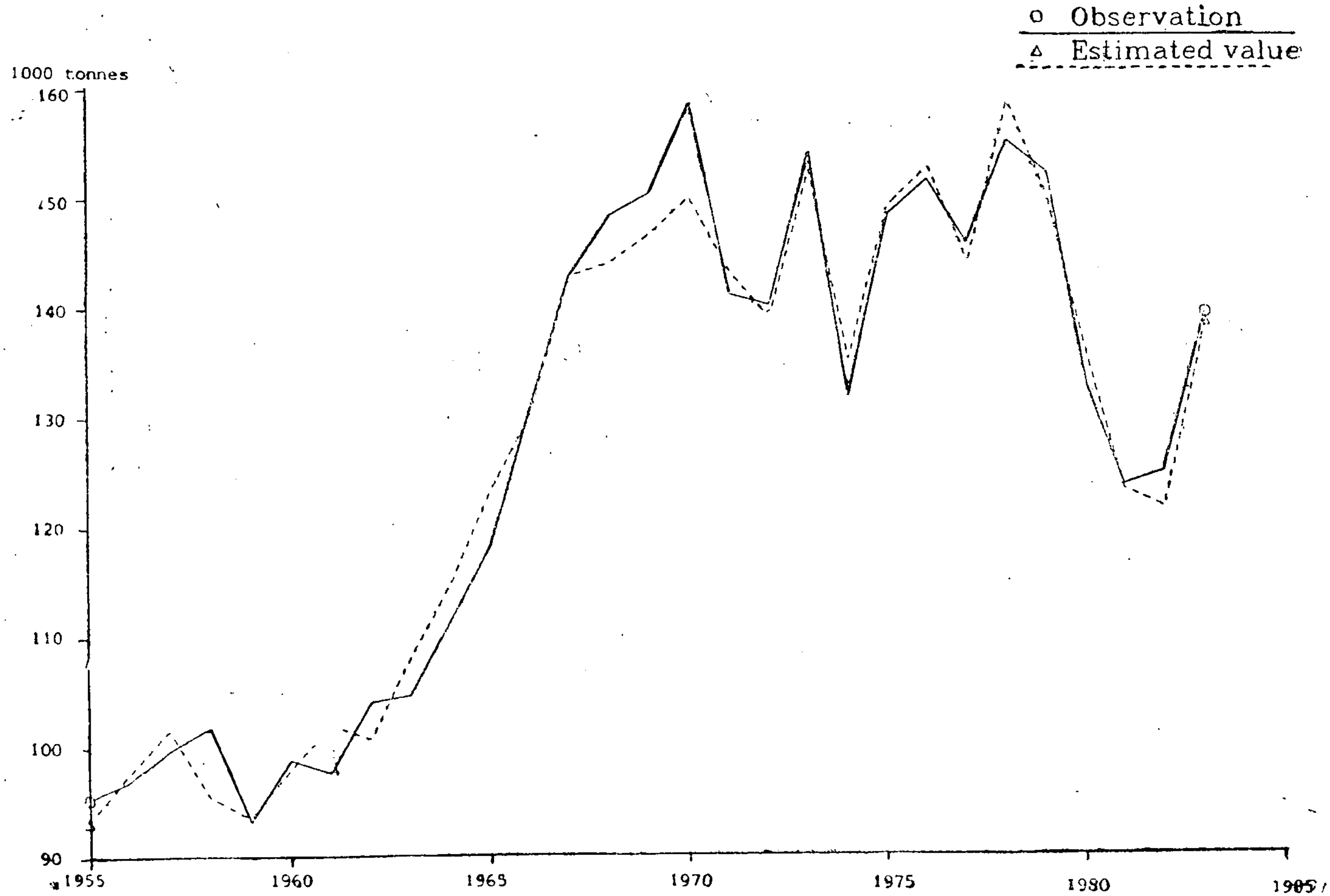

Fig. 3.2. Observations and estimated values for rubber production.

Projections of natural rubber production

An optimistic planting scenario

The analysis described in Chapter 3 may now be used as a tool to assess what the effects of planting policies on future natural rubber production may be. Projections will be made up to the year 2000.

Such projections depend on a lot of factors which can be broadly divided into two groups :

- planting policies
- other factors.

To the first group, planting policies, belong such variables as :

- total area under rubber
- replanting with rubber
- new planting
- uprooting for alternative land use.

Any consistent set of assumption for 1984 — 2000 may of course be fed into the model. Here, we have used the figures as shown in Table 4.1. Replanting and new planting levels may be considered rather optimistic. For the other variables the following assumptions have been used :

- the prices of NR in Colombo will run parallel to the world market prices as projected in Smit (1984) for the standard scenario ;
- rainfall will be normal ;

Using the above assumptions, projections are derived. They are presented in Table 4.2 and shown in Fig. 4.1. Production in 1000 tonnes will reach levels of around 150 in the second half of the 1980's, 200 in the first half of the 1990's when the replanting efforts of the 1980's reach their maximum momentum, production braking the 200 barrier around 1993.

It is interesting to have a look at area productivity as shown in Table 4.3. Yield per ha shows a dramatic increase in the sixties because of the replanting efforts in the 1950's. A similar development is shown in the 1980's and 1990's, showing the success of the current replanting schemes. Around the year 2000 average yield per ha will exceed 1,200 kg.

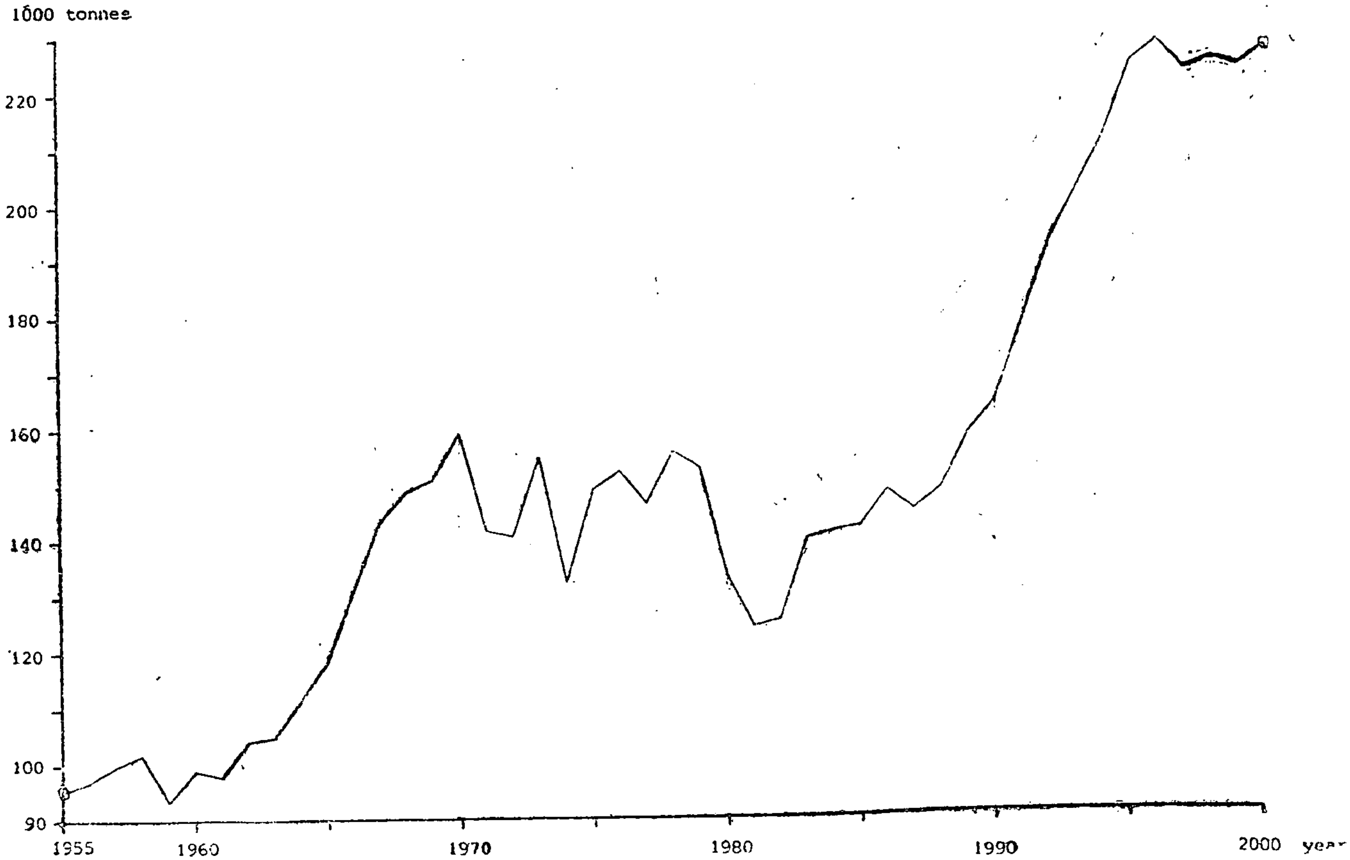

Fig. 4.1. Observations and projections of natural rubber production.

Table 4.1. *Assumptions on planting policies for natural rubber area (ha)*

Year	Total area	Estates Area	Estates Replanting	Estates New planting	Smallholdings Area	Smallholdings Replanting	Smallholdings New planting
1983	194,000	120,280	5,500	786	73,720	1,500	214
1984	193,000	117,730	6,000	800	75,270	1,500	200
1985	192,000	115,200	6,500	813	76,800	1,500	188
1986	191,000	114,600	6,500	406	76,400	1,500	94
1987	190,000	114,000	5,500	393	76,000	1,500	107
1988	188,500	113,100	4,500	375	75,400	1,500	125
1989	186,000	111,600	3,500	350	74,400	1,500	150
1990	185,000	111,000	3,500	350	74,000	1,500	150
1991	184,000	110,400	3,500	210	73,600	1,500	90
1992	183,000	109,800	3,500	210	73,200	1,500	90
1993	182,000	109,200	3,500	210	72,800	1,500	90
1994	181,000	108,600	3,500	210	72,400	1,500	90
1995	180,000	108,000	3,500	210	72,000	1,500	90
1996	179,000	107,400	3,500	140	71,600	1,500	60
1997	178,000	106,800	3,500	140	71,200	1,500	60
1998	177,000	106,200	3,500	140	70,800	1,500	60
1999	176,000	105,600	3,500	140	70,400	1,500	60
2000	175,000	105,000	3,500	140	70,000	1,500	60

Table 4.2. *Projections of natural rubber production (1000 tonnes)*

Year	Production
1984	141·3
1985	142·2
1986	148·8
1987	145·1
1988	149·1
1989	158·8
1990	164·6
1991	179·1
1992	193·5
1993	202·8
1994	212·5
1995	225·6

Table 4.2 *(Continued)*

Year	Production
1996	229·6
1997	224·2
1998	226·3
1999	224·9
2000	228·4

Table 4.3. *Productivity of rubber area*

	Average production per year[1]	Average area per year[2]	Average yield per ha per year[3]
1956 — 1960	98·1	237	414
1961 — 1965	107·2	228	470
1966 — 1970	146·6	219	670
1971 — 1975	143·5	207	692
1976 — 1980	148·0	196	755
1981 — 1985	134·5	193	697
1986 — 1990	153·3	188	815
1991 — 1995	202·7	182	1,114
1996 — 2000	226·7	177	1,281

(1) based on Tables 1.1 and 4.2, in thousand tonnes.
(2) based on Tables 2.2 and 4.1, in thousand ha.
(3) derived from the previous columns, kg, per ha.

Effects of alternative planting scenarios

In section on 'An optimistic planting scenario' planting policies were described which may be considered rather optimistic. The resulting projections of natural rubber production may be viewed accordingly. They are summarized again in Table 4.4. Table 4.5 shows results of a pessimistic scenario with replanting levels of around 1·6 % and Table 4.6 depicts a very pessimistic scenario with replanting levels of around 1 %. Of course, low levels of replanting leave more trees in the ground, resulting in higher production levels in the medium term. In 1990, the optimistic, pessimistic and very pessimistic scenarios give 164·6, 173·8 and 177·2, respectively. However, in the first half of the 1990's the order reverses with the optimistic scenario giving the highest figure : 225·6 as against 211·5 and 195·5 for the other scenarios. For the very pessimistic scenario, the highest value is reached in 1995 with a rapid and steady decline afterwards. The pessimistic scenario provides a slight decline in the second half of the 1990's, while the optimistic scenario yields rather stable levels of production. If planting is carried out at a reasonable level, production will reach levels of over 200,000 tonnes in the 1990's. It will depend on the level of replanting and new planting whether that level can be maintained after the year 2000.

Table 4.4. *An optimistic outlook on planting (1000 ha) and production (1000 tonnes)*

	Area	Replanting	New planting	Production
1983	194·0	7·0	1·0	139·9
1984	193·0	7·5	1·0	141·3
1985	192·0	8·0	1·0	142·2
1986	191·0	8·0	0·5	148·8
1987	190·0	7·0	0·5	145·1
1988	188·5	6·0	0·5	149·1
1989	186·0	5·0	0·5	158·8
1990	185·0	5·0	0·5	164·6
1991	184·0	5·0	0·3	179·1
1992	183·0	5·0	0·3	193·5
1993	182·0	5·0	0·3	202·8
1994	181·0	5·0	0·3	212·5
1995	180·0	5·0	0·3	225·6
1996	179·0	5·0	0·2	229·6
1997	178·0	5·0	0·2	224·2
1998	177·0	5·0	0·2	226·3
1999	176·0	5·0	0·2	224·9
2000	175·0	5·0	0·2	228·4

Table 4.5. *A pessimistic outlook on planting (1000 ha) and production (1000 tonnes)*

	Area	Replanting	New planting	Production
1983	194·0	7·0	1·0	139·9
1984	193·0	6·0	0·5	142·4
1985	192·0	5·0	0·5	146·0
1986	191·0	4·0	0·3	155·9
1987	190·0	4·0	0·3	154·1
1988	188·5	4·0	0·2	159·1
1989	186·0	3·0	0·2	169·1
1990	185·0	3·0	0·2	173·8
1991	184·0	3·0	0·1	184·7
1992	183·0	3·0	0·1	193·8
1993	182·0	3·0	0·1	197·2
1994	181·0	3·0	0·1	202·2
1995	180·0	3·0	0·1	211·5
1996	179·0	3·0	0·1	212·1
1997	178·0	3·0	0·1	204·6
1998	177·0	3·0	0·1	204·4
1999	176·0	3·0	0·1	201·4
2000	175·0	3·0	0·1	203·2

Table 4.6. *A very pessimistic view on planting (1000 ha) and production (1000 tonnes)*

	Area	Replanting	New planting	Production
1983	194·0	7·0	1·0	139·9
1984	193·0	3·0	0·3	144·0
1985	192·0	3·0	0·3	149·0
1986	191·0	2·0	0·2	160·3
1987	190·0	2·0	0·1	159·4
1988	188·5	2·0	0·1	164·8
1989	186·0	2·0	0·05	174·1
1990	185·0	2·0	0·05	177·2
1991	184·0	1·0	0·05	183·8
1992	183·0	1·0	0·05	189·1
1993	182·0	1·0	0·05	188·9
1994	181·0	1·0	0·05	190·2
1995	180·0	1·0	0·05	195·5
1996	179·0	1·0	0·05	193·4
1997	178·0	1·0	0·05	183·7
1998	177·0	1·0	0·05	179·8
1999	176·0	1·0	0·05	173·4
2000	175·0	1·0	0·05	171·2

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THE INTERNATIONAL NATURAL RUBBER AGREEMENT: AN ASSESSMENT

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INTRODUCTION

The International Natural Rubber Agreement (INRA) is the first commodity agreement concluded under the UNCTAD Integrated Programme for Commodities. This 5-year agreement came into force in October 1980 and was ratified and made operational at the first meeting of the International Natural Rubber Council (INRC) at Geneva in January 1981. At this meeting the principal Council officers were appointed and Kuala Lumpur named as the location for the INRC headquarters. Under this agreement price stabilisation was to be by the sole instrument of buffer stock (BS) operations of the International Natural Rubber Organisation (INRO). The agreement also provides for a 2 year extension upon its expiry in October 1985.

The BS operations began in November 1981 when natural rubber prices fell below the INRA-stipulated floor price of $ 2100 per tonne in Malaysian and Singapore dollar currency. These BS purchases continued through to April 1983 when prices came within the stabilisation price band after purchasing some 270,000 tonnes of BS purchases. Since April 1983, the BS operations have been dormant as price remained within the stabilisation band.

The eighth INRC meeting in July 1984 decided that instead of a 2 year extension from October 1985, the INRA will be renegotiated(1). From the mandate granted by all INRA member governments to renegotiate a " successor " agreement, it would seem that despite some earlier mixed feelings about the efficacy of the first INRA, member countries now believe in striving to improve this efficacy. It is therefore useful at this juncture to analyse the strategies by which BS operations can reduce the natural rubber price volatility over the longer term, and to indicate the associated operational difficulties.

This paper assesses the long term efficacy of the INRA by simulating the INRA rules in an econometric annual model of the world natural and synthetic rubber markets. In Section II the operational rules of the INRA are presented and translated into rules for simulations in the model (outlined in the Appendix). Aspects of INRA that need

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(1) A Preparatory Committee will meet during November 12 — 16, 1984 in Kuala Lumpur to prepare the materials for, and organise the Negotiating Conference scheduled for 1985 at Geneva.

consideration are then discussed in Section III. Section IV describes the rubber market briefly to highlight the underlying market dynamics that must be considered when operating the BS. The results of *ex ante* (for 1970 — 1980) and *ex post* (1985 — 1995) simulations of BS operations are presented in Section V. Finally, caveats for successful BS operations are given in Section VI.

Overall the simulation results highlight the role of the lagged structure of the rubber market in constraining the speed with which BS operations can support price, and hence the short run effectiveness of the BS. Conversely, the effectiveness of the accumulated BS in defending the ceiling price in any economic recovery depends on its size relative to the speed of the recovery.

Stabilisation aims and intervention price bands

The declared aims of the INRA (UNCTAD, 1979) are (i) to stabilise natural rubber price and (ii) to obtain steady growth in the natural rubber export revenues of the producing countries. The sole instrument for this market intervention is a buffer stock of 550,000 tonnes total capacity.

To guide the BS management on the timing of intervention, four sets of alternative price levels, and hence price bands, relating to optional and compulsory INRA interventions are specified. As shown in Fig. 1, these are (a) a reference price which approximates to the average price, (b) the intervention price band defined by upper and lower intervention prices delineated by the reference price plus and minus 15% respectively, (c) the trigger price band defined by the upper and lower trigger prices delineated by the reference price plus and minus 20% respectively, and (d) the indicative price band defined by upper and lower indicative prices delineated by the reference price plus and minus 28 5%. Thus the indicative prices are the floor and ceiling prices. The reference price is the key to successful stabilisation since it provides the nexus between the BS and the market and is the price upon which the remaining prices are determined.

In practice, BS operations will be conducted on the basis of the daily market indicator price (DMIP) which is a composite weighted average of daily official current-month prices on the Kuala Lumpur, Singapore, London and New York markets. For each market, the DMIP is an equally-weighted average of the prices for the RSS1, RSS3 and TSR20 grades of the natural rubber quoted in Malaysian or Singapore currency. (All prices are quoted in Singapore dollars hereafter). To monitor price behaviour, the average market price for 5 or more consecutive days provides the yardstick for evaluating the DMIP in relation to the INRA-specified price levels. When the DMIP remains higher than the reference price for 5 or more consecutive days, the DMIP is deemed to exceed the reference price.

To provide a measure of the extent of price support required at anytime, the total BS is differentiated into a *normal* BS of 400,000 tonnes and a *contingency* BS of 150,000 tonnes. In this two-part designation, the normal BS is expected to be adequate for defending the indicative price band under "normal circumstances". Should "normal circumstances" not obtain (which is tautologically defined to be when BS sales/purchses amounting to 400,000 tonnes fail to bring price within the trigger price band where intervention is optional), the contingency BS will be mobilised when either (a) the DMIP

Upper Indicative Price (2 1/2 years)	$2100 + 28.5% = $2700	
Price for bringing in Contingency BS	$2610	Compulsory BS Sales
Upper Trigger Price	$2100 + 24.0% = $2520	
		Optional BS Sales
Upper Intervention Price	$2100 + 15.0% = $2415	
Reference Price (1 1/2 years)	$2100	No BS Operations Except Stock Rotation
Lower Intervention Price	$2100 - 15.0% = $1790	
		Optional BS Purchases
Lower Trigger Price	$2100 - 24.0% = $1680	
Price for Bringing Contingency BS	$1590	Compulsory BS Purchases
Lower Indicative Price (2 1/2 years)	$2100 - 28.5% = $1500	

Fig. 1. Price ranges specified for INRA BS operations.

lies in the band where intervention is compulsory or (b) the DMIP reaches the trigger level. Unless the INRC votes to the contrary, the contingency BS will be mobilised when the DMIP reaches one of the averages of the trigger and indicative prices (*i.e.* $ 1,590 and $ 2,610). Thus when necessary, the entire 550,000 tonnes BS will be used to ensure stabilisation within the floor and ceiling prices.

Basically, the reference price is to remain for 1½ years at $ 2,100, while the indicative (floor and ceiling) prices of $ 1,500 and $ 2,700 are valid for 2½ years. Provision for intervention price revisions during the 5-year agreement period is given by clauses couched in terms of the speed of BS accumulation/releases. To check that the predetermined reference price is appropriate, the net change in BS volume cannot exceed 100,000 tonnes within the 1½ year validity period of the reference price. To ensure effective utilization of the BS resources, the net total BS sales/purchases since the INRA enforcement or since any reference price revision may not exceed 300,000 tonnes. Thus the need for revising the reference and indicative prices is determined by movements in the DMIP and/or the net change in BS holdings.

Should the 6 month average DMIP remain outside the trigger price band despite the BS intervention, the reference price will be revised up/down by 5%. Furthermore, should the net change in BS exceed either 100,000 tonnes within 1½ years or 300,000 tonnes at any time, then the reference price will be revised accordingly by 3%, unless the INRC decides otherwise.

Following any reference price revision, the indicative prices can be revised whenever the reference price is either revised by more than 5% within 1½ years or more than 3% within 2½ years and the DMIP still falls outside the indicative price bands in the ensuing 60 days.

Some unexplored aspects of the INRA

Assuming the desirability of price stabilisation, the first aspect of INRA to consider is that of feasibility. Although the INRA is intended to function for a 5-year term, the INRA price bands are specified up to terms of 1½ and 2½ years only after which they are subject to review and revision. While frequent price band revisions should enhance the effectiveness of the BS operations, some more automatic rule for adjusting the reference price to take account of the price trend forecast may be called for to avoid time-consuming and costly negotiations.

Another aspect of INRA to consider is that of *prospective* BS operations from a longer term perspective. Prospective BS operations refer to operating the BS where the INRA rules stipulate such operations to be optional. Given the market dynamics, prospective operations may be more efficient in reducing the price volatility than later intervention, after the market pressure on price has gathered momentum. As will be seen, stabilisation over the longer term tends to entail prospective buying or selling considerably in advance of the anticipated adverse price movement. It is here that the insights and foresight of the BS management about the speed of supply response and demand adjustments becomes critical.

The INRA is aimed at partial stabilisation to reduce, rather than to eliminate, price variability. For a given BS, the success of partial stabilisation depends on (a) the choice of the reference price level and (b) the effective interaction between the BS and market price.

The advantage of partial stabilisation is that the long run trend price about which prices are to be stabilised need not be known to the degree of precision required for successful complete stabilisation. In this respect partial stabilisation is easier to operate since a higher margin of error is tolerable for the reference price. However, the larger the difference between the reference and trend prices, the larger the BS required and the more onesided the intervention will be. This raises the question of whether the stabilised price bands have to be equidistant from the reference price.

While INRA specifies equidistant price band about the $ 2,100 reference price, no explanation is given for the choice of the price level nor the equidistant principle. For a self-liquidating BS, equidistant price bands are valid only when prices are either (a) symmetrically distributed about a stationary trend or (b) distributed about a non-stationary trend and skewed to the left (right) in the lower (upper) price range. If these stringent conditions are not met, then a self-liquidating BS need not invoke stabilizing about equidistant price bands. Hence the choice of equidistant/non-equidistant price bands cannot be determined independently of the expected trend price behaviour. As the simulation results will later show, the rubber market dynamics are such that insistence on equidistant price band stabilisation would mean higher BS accumulation than necessary to defend the floor price.

On the question of the BS capacity, it is not explained how the 400,000 tonnes " normal stocks " for market stabilisation under " normal circumstances " is determined, and the definition given in the INRA is tautological. Furthermore, effective interaction between the BS and market price involves assumptions about private stockholding behaviour in the presence of BS interventions. In general the effect of public storage supply on private stockholdings depends on (a) the existing levels of public and private stockholdings, (b) the level of financial resources for the supply of public storage and (c) the sizes of (a) and (b) relative to the market fluctuations arising from random disturbances (for example, see Siamwalla, 1981). Consequently, storage supply may shift between the two sources, with the scope for public displacement of private storage generally being proportional to the financial resources available for public storage.

These considerations of the correct identification of the long run trend price and the behaviour of private stockholdings highlight the reliance of BS operations on the judgement of the BS manager. In turn this leads to the problems of understanding the dynamics inherent in the system, the ability of the BS manager to distinguish reliable from false price signals, and the discretionary use of prospective BS operations. Thus the problems associated with the feasibility of BS operations and management to attain these ends cannot be overemphasised.

Besides price stabilisation, the INRA is also aimed at the steady growth of export incomes of the producing countries. This may be attained (a) by obtaining a higher average price under stabilisation and (b) by inducing more consumption (via input substitution) and production of natural rubber through reduced price fluctuations and uncertainty. Since export income growth may be viewed as an income transfer from consuming to producing countries, this raises the question of consumers' agreement to and participation in such price stabilisation arrangements, bearing in mind the known availability of synthetic rubbers. Even with consumers' participation, the compatibility of price stabilisation and income growth cannot be assumed.

Model structure reflecting the world rubber market

The econometric model of the world natural and synthetic rubber market by Tan (1984) is used to simulate the INRA rules. The model is essentially a supply-demand model, disaggregated by the main natural rubber producing, and natural and synthetic rubber consuming countries. With the synthetic rubber market modelled explicitly, the 87-equation model can be viewed as consisting of two submodels, one for each group of rubber, and interacting through their relative price effects on consumption. The causality between natural and synthetic rubber prices in the market is reflected in the causal structure of the model which indicates co-determination of synthetic rubber production and price. Synthetic rubber production and price then determine natural rubber price, production and consumption as well as some consumption of synthetic rubbers. The remaining synthetic rubber consumption is then determined from which total synthetic rubber consumption and stocks are determined. In summary, natural rubber price formation in the historical period has been causally dependent on synthetic rubber price, and co-determined with natural rubber production and natural as well as synthetic rubbers consumption.

Several assumptions are implicit in using the model to simulate BS operations a la INRA. These are the continued validity of the existing market structure as represented by the model, and of the leading role played by the London market in natural rubber price formation. For in the historical period, natural rubber prices in the various primary and terminal markets have been determined ultimately by the London spot price which, to a large extent, was influenced by variations in the natural rubber stockholdings in the consuming regions. Thus the behaviour of private stockholdings in the consuming regions has a bearing on the potential impact of BS operations since the stabilisation programmes could affect private stockholding behaviour.

The reasons for a possible reduction in the influence of the London spot price in future are that the oil crises and ensuing higher synthetic rubber prices have led to greater reliance on natural rubber supply through long term contracts. The potential shift in focus to other markets is also suggested by the recent establishment of a commodities exchange in Kuala Lumpur and by the fact that Singapore, an active centre for natural rubber trading, is not party to INRA. Consequently, the longer term reactions and speculative activities of Malaysian and Singapore traders to BS operations remain to be seen and thus have not been incorporated in the simulations presented here. (In terms of model simulations, a different trading behaviour would necessitate a change in the values of the parameters used in the stockholding equations). Finally, it is assumed that the BS manager operates with sufficient financial resources.

To understand the dynamics of the world rubber market, model simulations of the BS rules were conducted. The basis for simulating BS operations is the RSS1 - grade price of natural rubber. The findings from *ex post* and *ex ante* simulations of BS operations with prospective buying and selling will now be discussed.

Simulations of BS operations for price stabilisation

This section discusses the results of two cases of *ex-post* stabilisation (from 1970 to 1980) and two of *ex-ante* stabilisation (from 1985 — 1995). The 1970 — 80 decade was marked by, amongst other events, the sharp rise in oil price. This bears directly on the natural rubber market through higher synthetic rubber prices and lower growth of the transport sector which is a major outlet for natural rubber. It is therefore instructive to appraise the schedule of BS operations that would have been required to stabilise price during this eventful period (Phase III) when, as can be seen from Fig. 2, the long term natural rubber price trend reversed, and the amplitude of price fluctuations widened from those during the previous decade of low and stable oil price (for further details see Tan, 1984 : 6.6).

Case 1 : BS operations during 1970 — 1980 were simulated to stabilise price along the long term trend price with unchanged private stockholding behaviour. The actual and the stabilised price paths over time are shown in Fig. 3 with the levels of BS purchases (positive values) and sales (negative values) shown against their respective intervention years. Over the stabilisation period the BS holding will average 65,000 tonnes. The effects of this stabilisation programme, measured in terms of the average volumes and values of production and consumption and their instability indices are presented in Tables 1 (a) - (c).[2]

At the global level, Table 1(a) shows that stabilisation along the long term trend price will increase the average and total natural rubber output during the period, but will lower the average and total natural rubber consumption. The market intervention will also reduce both production and consumption instability. While stabilisation will reduce the instability indices for export earnings and consumption expenditures, the results also show that the higher production will yield higher export earnings but that the lower consumption will cost more. The simultaneous increases in export earnings and consumption expenditures reflect the scope for income transfer from the consuming to the producing countries. This annual income transfer of US $ 92 million from price stabilisation is about 3% of the average annual consumption outlay. Assuming no change in the private stockholding behaviour, Table 1(a) shows that while private stockholdings in the producing regions and afloat (on board ships) are reduced under intervention, the average private stockholdings in the consuming countries will increase as will its level of instability.

Table 1 (b) presents the stabilization effects on the major producing countries. Except for Indonesia and Thailand, the stabilisation programme is seen to benefit the producing countries by reducing the instability of production and export earnings. For Indonesia production instability is not improved by the stabilisation programme while price stabilisation will lead to lower output and export earnings for Thailand.

(2) The instability index used here is the UNCTAD index, given by

$$\Sigma_i \mid Y_i - \bar{Y}_i \mid / \bar{Y}$$

where Y_i and $\bar{Y}_i$ are actual and trend values, respectively

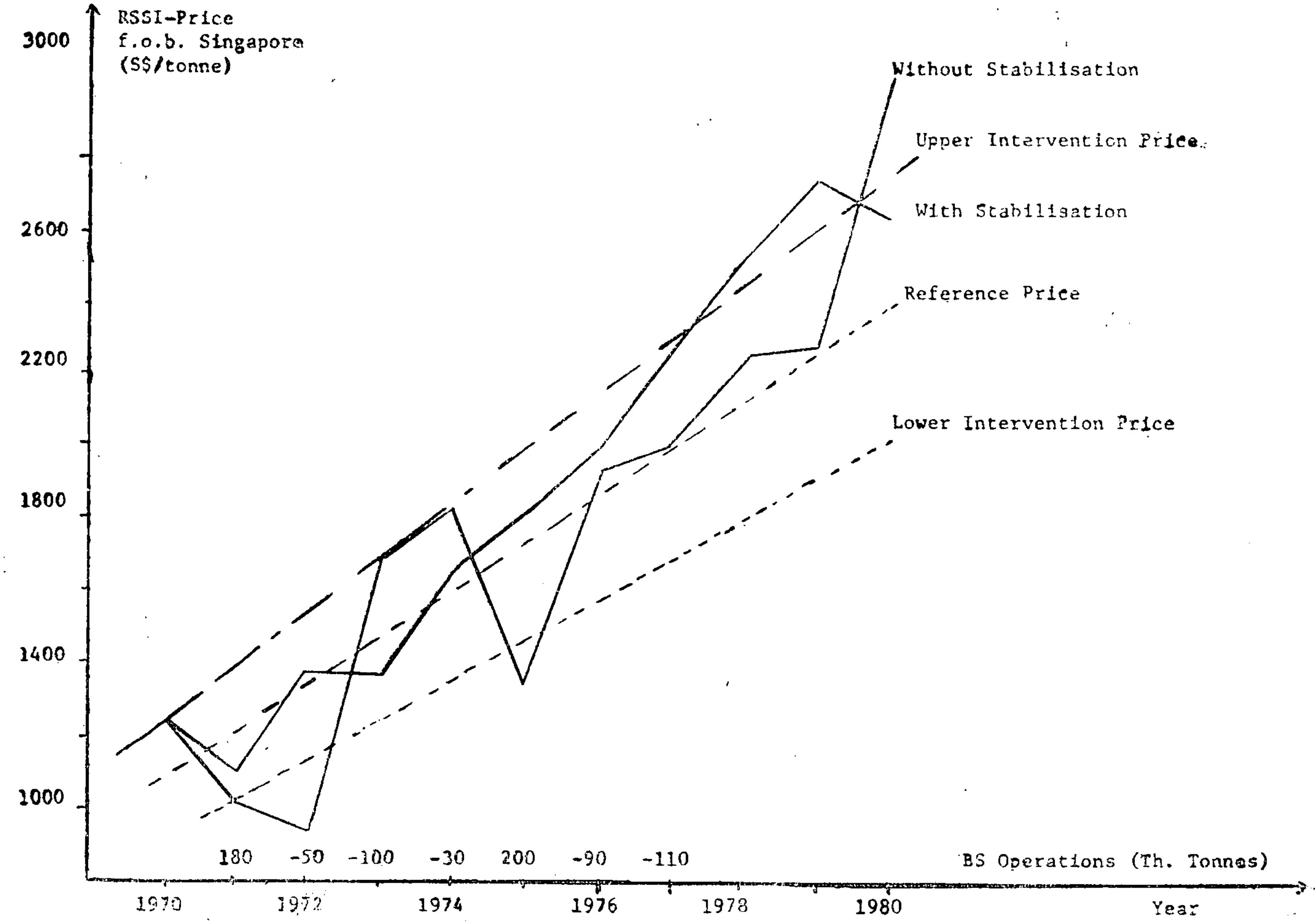

Fig. 2. Time-paths of average monthly and annual natural rubber prices in Singapore, 1953 - 1983.

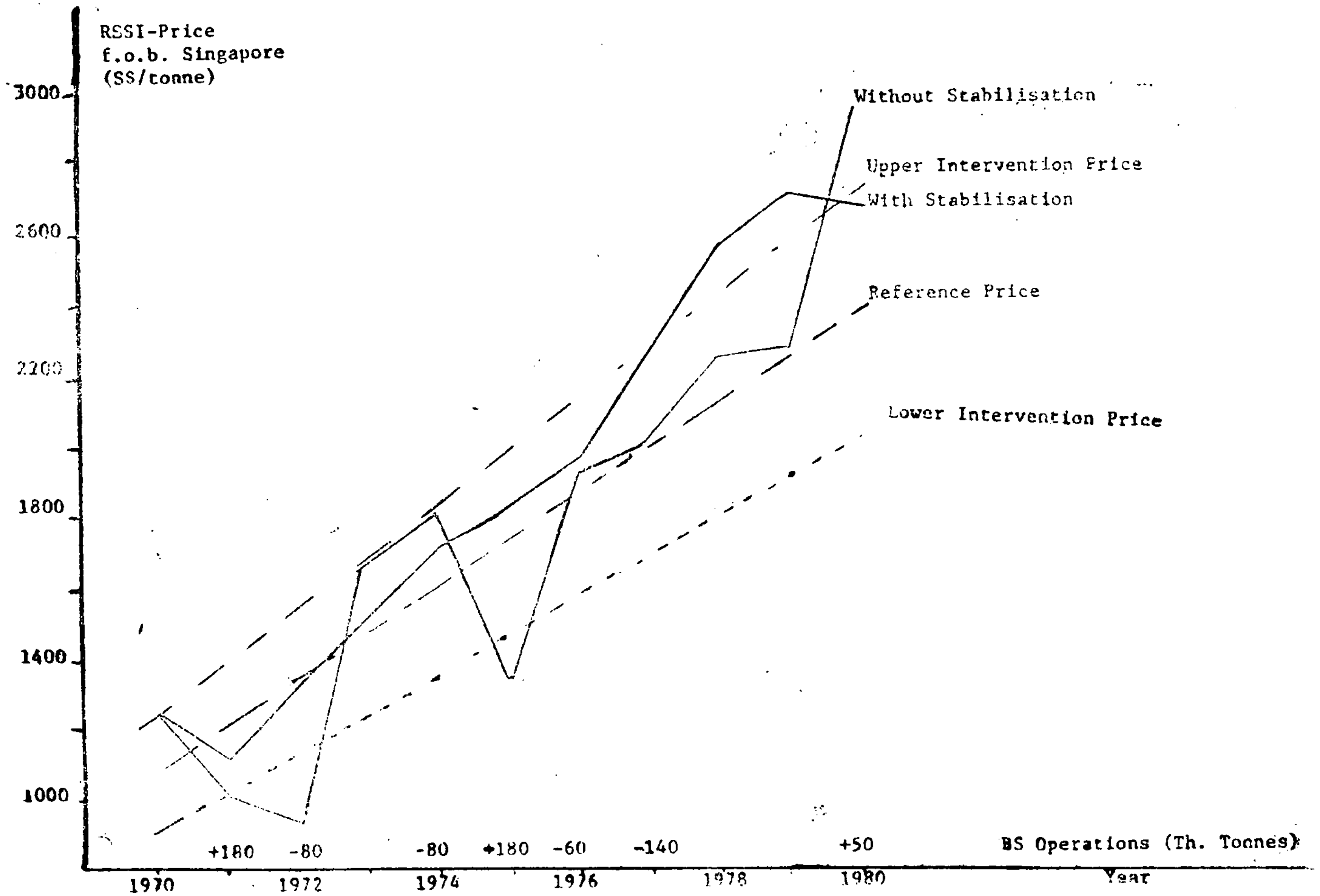

Fig. 3. BS operations with unmodified private stockholding behaviour.

Table 1(a), ***Summary of effects of price stabilization around the long term trend price, 1970 — 1980***

Variable	Average level under: Free market	Average level under: Market intervention	Change in average level due to market intervention	Instability index under: Free market	Instability index under: Market intervention
World NR production (thousand tonnes)	3512·00(0·0055)	3543·40(0·0028)	31·39	0·6207	0·4522
World NR consumption (thousand tonnes)	3518·50(0·0046)	3445·10(0·0039)	—73·40	0·5662	0·5192
NR stocks in producing regions and afloat (thousand tonnes)	788·65(0·0028)	743·69(0·0010)	—44·96	0·4669	0·2573
NR stocks in consuming regions (thousand tonnes)	764·50(0·0018)	776·54(0·0107)	12·04	0·3362	0·8923
World NR export earnings (US $ million)	2,541·30(0·2156)	2,633·30(0·1401)	92·00	3·695	3·1929
World NR consumption expenditures (US $ million)	2,927·00(0·2356)	2,935·10(0·1662)	8·10	3·8949	3·5142
World NR real export earnings (million 1983 US $)	3,431·50(0·0420)	2,643·40(0·0054)	211·90	1·6928	0·5540
World NR real consumption expenditures (million 1983 US $)	3,929·20(0·0465)	4,008·40(0·0141)	79·20	1·7857	0·9199

Note :— Figures within parentheses denote coefficients of variation of the distributions of values from which the corresponding averages are derived.

Table 1(b). *Summary of price stabilization effects on major producers, 1970 — 1980*

Country	Average natural rubber output (a)				Average natural rubber export earnings (b)			
	Without stabilization		With stabilization		Without stabilization		With stabilization	
	Volume	Instability index	Volume	Instability index	Value	Instability index	Value	Instability index
Africa	207·14(0·0045)	0·5075	209·54(0·0036)	0·4999	168·98(0·1464)	2·7947	174·03(0·1000)	2·5890
Brazil	23·08(0·0145)	0·9977	24·11(0·0849)	0·7404	18·00(0·2923)	4·3539	19·55(0·1922)	3·8623
Indonesia	866·50(0·0055)	0·5717	905·56(0·0051)	0·6177	682·06(0·2692)	4·0713	726·53(0·1640)	3·5023
Malaysia								
Estates	632·64(0·0005)	0·4508	638·18(0·0018)	0·3293	393·75(0·0809)	2·3215	405·16(0·0510)	1·8182
Smallholders	804·13(0·0175)	1·0356	803·64(0·0091)	0·8300	481·60(0·1732)	3·4162	509·12(0·1135)	2·8064
Sri Lanka	145·71(0·0032)	0·4928	145·00(0·0009)	0·2272	113·92(0·1879)	3·5336	116·15(0·1135)	2·8551
Thailand	412·23(0·0263)	1·3643	386·53(0·0191)	1·1741	337·37(0·3501)	4·8097	322·67(0·2286)	4·1250

Notes : (a) Average natural rubber output volume is given in thousand tonnes.

(b) Average natural rubber export earnings value is given in million US dollars.

Figures within parentheses denote coefficients of variation of the distribution of values from which the corresponding averages are derived.

Table 1(c). *Summary of price stabilization effects on major consumers, 1970 — 1980*

Country	Average natural rubber consumption (a)				Average natural rubber consumption expenditure (b)			
	Without stabilization		With stabilization		Without stabilization		With stabilization	
	Volume	Instability index	Volume	Instability index	Value	Instability index	Value	Instability index
France	165·85(0·0029)	0·4092	165·07(0·0023)	0·4104	140·37(0·2339)	3·7217	141·21(0·1569)	3·4374
Fed. Rep. of Germany	190·87(0·0021)	0·3970	188·180(0·0006)	0·2121	157·45(0·1554)	3·0374	157·54(0·1406)	3·1236
Italy	124·30(0·0037)	0·5066	122·49(0·0008)	0·2387	104·22(0·2057)	3·6010	104·15(0·1419)	3·2420
Japan	333·32(0·0165)	1·0424	332·65(0·0099)	0·8634	267·92(0·3384)	4·6689	273·82(0·2067)	3·9378
United Kingdom	162·23(0·0133)	0·9763	160·10(0·0087)	0·7901	128·65(0·1029)	2·4969	130·74(0·0775)	2·3877
United States	695·08(0·0093)	0·8299	684·36(0·0073)	0·7508	610·33(0·1779)	3·4847	618·77(0·1411)	3·2205

Notes : (a) Average natural rubber consumption volume is given in thousand tonnes.

(b) Average natural rubber consumption expenditure is given in million US dollars.

Figures within parentheses denote coefficients of variation of the distributions of values from which the corresponding averages are derived

Table 1 (c) presents the stabilisation effects on the major consuming countries and show that countries benefit differentially. While stabilisation will lower global consumption, consumption in Japan, UK and the US are seen to increase. For the majority of countries, lower instability indices for consumption volumes and values are obtained.

Some insights into the question of stabilisation about equidistant or non-equidistant price bands can also be gleaned from Fig. 3. The behaviour of price in the historical period is such that for the BS to successfully defend the ceiling price during 1979 — 1980, the BS purchases in 1971 and 1975 have to be higher than warranted by the floor support price. Thus the resulting price path could equally have been an outcome of stabilisation about non-equidistant price bands.

Case II : Since it is known that private stockholding behaviour can change in the presence of a stabilisation programme, an assessment of the sensitivity of stabilisation effects to an assumed change in private stockholding behaviour is attempted. In line with the model structure of consuming region stocks playing a key role in the London spot price formation, the assumption in this simulation is that stockholdings in the consuming regions are shifted out partially. Using the accumulated BS of about 270,000 tonnes which approximates 30% of the stocks in the consuming regions in recent years as a guideline, the consuming region's stocks will be adjusted downwards by a factor of 0·3 to proxy the shift of stockholding burden to the INRO.

Fig. 4 illustrates the actual and stabilised price paths and the attendant schedule of BS operations. In comparison with the BS operations in Case I, the stabilised price path is smoother with the average BS holding of 80,000 tonnes, and the BS authority, will end the stabilisation period with a positive balance of 50,000 tonnes stocks in 1995. Furthermore, although the schedule of BS operations may differ by as much as 100,000 tonnes from those in Case I for each corresponding year, the mid-period BS holdings in 1975 are identical at 200,000 tonnes.

Tables 2 (a) — (c) quantifies the stabilisation effects. Table 2 (a) reveals that the global stabilisation effects are the same qualitatively as in Case I. Quantitatively, however, the Case II stabilisation yields slightly higher total output and total export earnings than for Case I, with slightly lower world consumption volume and at higher cost. As for Case I the price stabilisation programme effectively stabilises export earnings.

The major producing countries benefit from stabilisation in terms of higher output and export earnings, both with reduced instability. However, intervention reinforces the Indonesian production instability and Thai export earnings instability. For the major consuming countries the stabilisation effects in Case II are similar to those for Case I, both qualitatively and quantitatively.

These simulation results vindicate the hypothesis that the natural rubber market instability stems in part from the stockholding behaviour in the consuming regions.

Case III : Given that the INRA is scheduled for renegotiation in 1985 from the likely position of having an initial BS of about 270,000 tonnes (assuming no BS releases between August 1984 and October 1985), *ex-ante* simulations with the model can be used to explore alternative schedules of BS operations to stabilise an assumed scenario for the coming decade.

Table 2 (a). *Summary of effects of price stabilization around the long term trend price, 1979 — 1980*

Variable	Average level under		Change in average level due to market intervention	Instability index under	
	Free market	Market intervention		Free market	Market intervention
World NR production (thousand tonnes)	3,512·00(0·0055)	3,553·70(0·0029)	41·79	0·6207	0·4519
World NR consumption (thousand tonnes)	3,518·50(0·0046)	3,438·60(0·0038)	—79·90	0·5662	0·5223
NR stocks in producing regions and afloat (thousand tonnes)	788·65(0·0028)	746·27(0·0011)	—42·38	0·4669	0·2523
NR stocks in consuming regions (thousand tonnes)	764·50(0·0018)	756·87(0·0078)	—10·37	0·3362	0·7515
World NR export earnings (US $ million)	2,541·30(0·2156)	2,681·20(0·1424)	139·90	3·6950	3·2016
World NR consumption expenditures (US $ million)	2,927·00(0·2356)	2,983·00(0·1663)	56·00	3·8949	3·5211
World NR real export earnings (million 1983 US $)	3,431·50(0·0420)	3,706·00(0·0068)	274·50	1·6928	0·7329
World NR real consumption expenditures (million 1983 US $)	3,929·20(0·0465)	4,073·80(0·0147)	144·60	1·7857	1·0013

Note : Figures within parentheses denote coefficients of variation of the distribution of values from which the corresponding averages are derived.

Table 2 (b). *Summary of price stabilization effects on major producers, 1970 — 1980*

Country	Average natural rubber output (a)				Average natural rubber export earnings (b)			
	Without stabilization		With stabilization		Without stabilization		With stabilization	
	Volume	Instability index	Volume	Instability index	Value	Instability index	Value	Instability index
Africa	207·14(0·0045)	0·5075	209·83(0·0035)	0·5008	168·98(0·1464)	2·7947	177·41(0·1011)	2·5827
Brazil	23·08(0·0145)	0·9977	24·29(0·0081)	0·7054	18·00(0·2923)	4·3539	20·10(0·1963)	3·8788
Indonesia	866·50(0·0055)	0·5717	910·66(0·0053)	0·6102	682·06(0·2692)	4·0713	744·80(0·1675)	3·5105
Malaysia								
Estates	632·64(0·0005)	0·4508	640·01(0·0017)	0·3235	393·75(0·0809)	2·8215	410·03(0·0501)	1·7276
Smallholders	804·13(0·0175)	1·0356	803·67(0·0092)	0·8240	481·60(0·1732)	3·4162	512·26(0·1161)	2·8040
Sri Lanka	145·71(0·0032)	0·4928	144·87(0·0008)	0·2286	113·92(0·1879)	3·5336	118·09(0·1135)	2·8287
Thailand	412·23(0·0263)	1·3643	386·77(0·0196)	1·1789	337·37(0·3501)	4·8097	329·14(0·2335)	4·1710

Notes : (a) Average natural rubber output volume is given in thousand tonnes.
(b) Average natural rubber export earnings value is given in million US dollars.
Figures within parentheses denote coefficients of variation of the distribution of values from which the corresponding averages are derived.

Table 2 (c). *Summary of price stabilization effects on major consumers, 1970 — 1980*

Country	Average natural rubber consumption (a)				Average natural rubber consumption expenditures (b)			
	Without stabilization		With stabilization		Without stabilization		With stabilization	
	Volume	Instability index	Volume	Instability index	Value	Instability index	Value	Instability index
France	165·85(0·0029)	0·4092	164·56(0·0023)	0·4069	140·37(0·2339)	3·7217	143·25(0·1595)	3·4608
Fed. Rep. of Germany	190·87(0·0021)	0·3970	187·51(0·0006)	0·2099	157·45(0·1554)	3·0374	161·25(0·1187)	2·9223
Italy	124·30(0·0037)	0·5066	121·89(0·0007)	0·2322	104·22(0·2057)	3·6010	105·47(0·1441)	3·2517
Japan	333·32(0·0165)	1·0424	332·05(0·0100)	0·8696	267·92(0·3384)	4·6689	278·45(0·2107)	3·9620
United Kingdom	162·23(0·0133)	0·9763	159·03(0·0089)	0·7769	128·65(0·1029)	2·4969	132·10(0·0784)	2·3423
United States	695·08(0·0091)	0·8299	683·03(0·0074)	0·7618	610·33(0·1779)	3·4847	627·82(0·1397)	3·2300

Notes : (a) Average natural rubber output volume is given in thousand tonnes.
(b) Average natural rubber export earnings value is given in million US dollars.
Figures within parentheses denote coefficients of variation of the distribution of values from which the corresponding averages are derived.

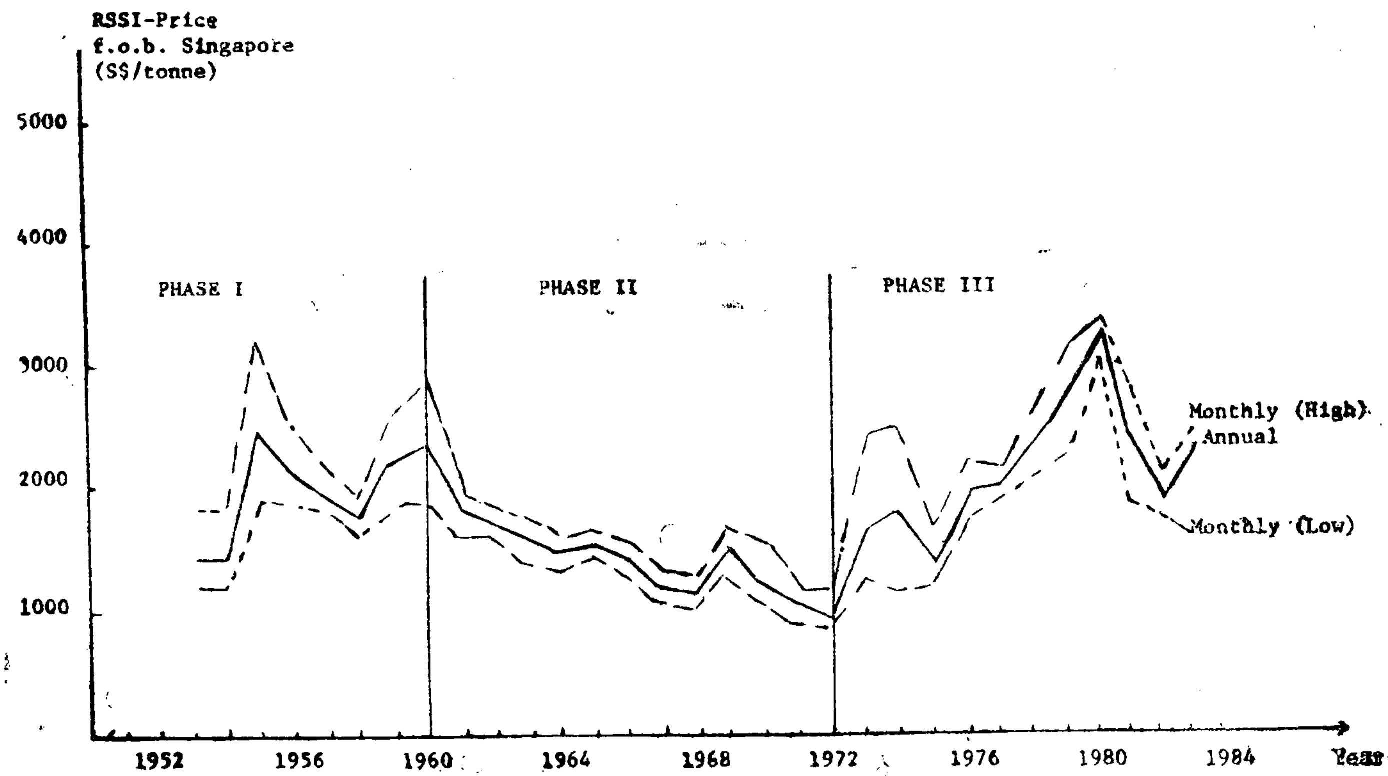

Fig. 4. BS operations with modified private stockholding behaviour, 1970 - 1980.

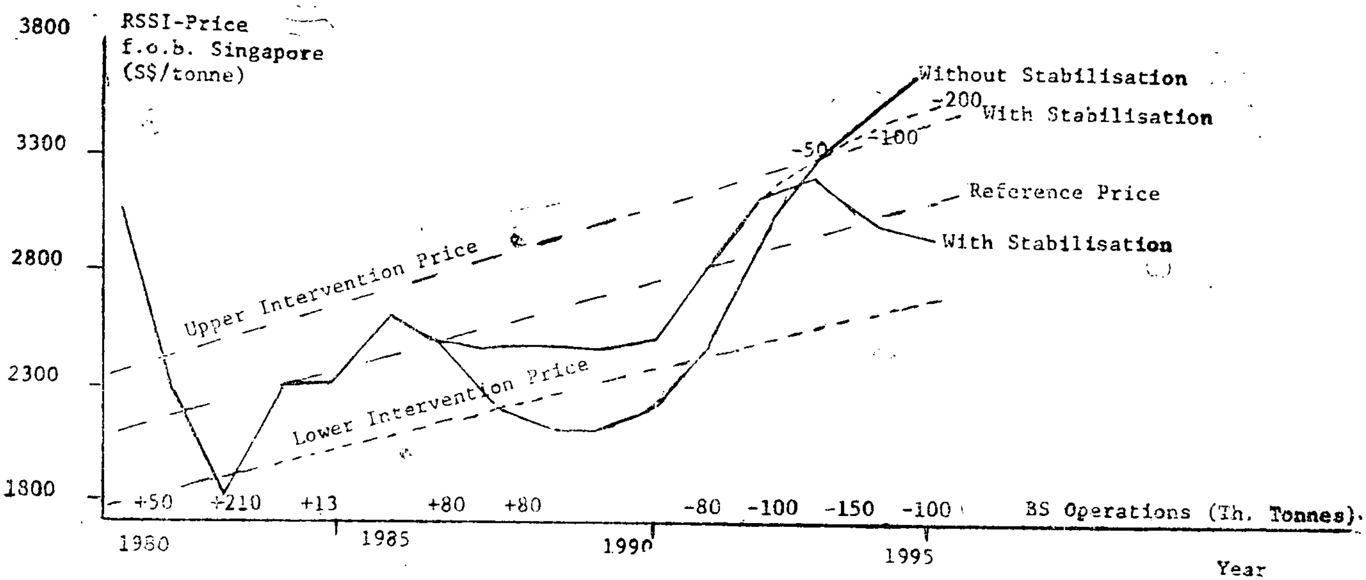

Fig. 5. BS operations for price stabilisation, 1985 - 1995.

The scenario employed here assumes GNP growth in the industrial countries averaging 2·8% during the 1984 — 86 period and 3·2% during the 1987 — 1995 period. As Fig. 5 for this scenario shows, the natural rubber price will fall from 1986 through to 1989 and rise from 1990 to 1995. This projected price behaviour can be explained largely in terms of the dynamics of supply response in rubber production. Apart from having a gestation period of some 5 to 8 years, the yield of rubber trees tends to peak about 5 to 6 years after first production so that the productivity of a tree becomes maximal about 10 — 14 years after planting. The low prices projected for the second half of the 1980s reflect the lagged supply response to the high rubber prices in the early 1970s and the expectation soon after the oil crisis that synthetic rubbers had lost their price advantage. Since natural rubber competes with synthetic rubbers, the low prices in the 1980s will induce material input substitution favouring natural rubber as its price fall in relation to those of synthetic rubbers. As natural rubber consumption increases while its supply is inelastic in the short to medium term, the tightening of the natural rubber market causes price to rise again. Assuming the industrial countries continue to grow, the continued increased demand for natural rubber will reinforce the tightening market and increase price further.

Fig. 5 shows two alternative schedules of non-stochastic (3) simulations of BS operations to stabilise price with the initial BS of 1985 being liquidated by 1995. To support the floor price the BS management will need to add onto the existing stockpile by buying about 80,000 tonnes annually in 1987 and 1988. By 1992 the BS releases will be required to defend the ceiling prices through to 1995. Two stabilised price paths are shown for the 1992 — 1995 period to illustrate the impact of different rates of BS releases.

Tables 3 (a) — (c) summarises the effects of a stabilisation programme ending on the lower price path in Fig. 5. On this path the average BS holding is 280,000 tonnes. Qualitatively and quantitatively, the results indicate that the effects are similar to those for Cases I and II. More importantly, they show that the non-release of the BS during late 1983 and early 1984 (when the market price exceeded the upper intervention price) was appropriate to the stabilisation strategy about the long term trend price of this scenario. However, it should be mentioned that BS operations also incur operational (carrying and rotation) and administrative costs. These costs must be considered in an overall evaluation of the net result of BS price stabilisation. Where the average BS holding during the stabilisation is high, as is the case here, it may be envisaged that gains from stabilisation may be offset by the BS operation outlays.

Caveats for successful stabilisation

The three main results of *ex post* and *ex ante* simulations of the BS operations may now be summarised.

(3) The simulations reported here are non-stochastic in nature. Although stochastic simulations are preferable for realism, the use of non-stochastic simulations does not detract from the findings because the model used here is *annual* in nature. Since an annual model is essentially a long term model, the non-stochastic simulations permits one to concentrate the analysis on the dynamic effects of market interventions arising from the long lagged structure of the model. However, the INRA intervention is based on daily market prices and all the constraint clauses are tied to these prices. Since these daily price variations are assumed away in non-stochastic simulations, it is obvious that the problems of price stabilisation are understated here. In this sense, the non-stochastic approach may be seen to provide the most favourable test of the INRA proposals.

Table 3 (a). *Summary of effects of price stabilization around the long term trend price, 1983 — 1995*

Variable	Average level under: Free market	Average level under: Market intervention	Change in average level due to market intervention	Instability index under: Free market	Instability index under: Market intervention
World NR production (thousand tonnes)	5,281·20(0·0244)	5,297·80(0·0226)	16·60	1·7410	1·7112
World NR consumption (thousand tonnes)	5,206·60(0·0228)	5,172·90(0·0221)	—33·70	1·7392	1·6886
NR stocks in producing regions and afloat (thousand tonnes)	770·24(0·0007)	769·39(0·0014)	— 0·85	0·2744	0·4279
NR stocks in consuming regions (thousand tonnes)	1,187·30(0·0572)	1,171·60(0·0674)	—15·70	2·8089	2·8938
World NR export earnings (US $ million)	6,135·20(0·1121)	6,144·00(0·0630)	8·80	3·7541	2·8456
World NR consumption expenditures (US $ million)	6,691·30(0·1232)	6,631·80(0·0697)	—59·50	3·9803	3·075
World NR real export earnings (million 1983 US $)	3,889·40(0·0168)	3,944·50(0·0045)	55·10	1·5140	0·7275
World NR real consumption expenditures (million 1983 US $)	4,237·20(0·0220)	4,254·80(0·0067)	17·60	1·7625	0·8890

Figures within parentheses denote coefficients of variation of the distribution of values from which the corresponding averages are derived.

Table 3 (b). *Summary of price stabilization effects on major producers, 1983 — 1995*

Country	Average natural rubber output (a)				Average natural rubber export earnings (b)			
	Without stabilization		With stabilization		Without stabilization		With stabilization	
	Volume	Instability index	Volume	Instability index	Value	Instability index	Value	Instability index
Africa	372·66(0·1578)	4·7026	374·42(0·1561)	4·6922	505·99(0·3283)	6·6490	502·58(0·2414)	5·8599
Brazil	33·43(0·0109)	1·2023	34·56(0·0179)	1·5785	41·40(0·0912)	3·5139	43·06(0·0663)	3·0177
Indonesia	1,301·20(0·0225)	1·5371	1,309·00(0·0205)	1·5758	1,618·60(0·1143)	3·6049	1,625·70(0·0547)	2·5331
Malaysia								
Estates	711·98(0·0182)	1·4203	716·82(0·0180)	1·4227	723·08(0·0574)	2·6636	728·93(0·0377)	2·0910
Smallholders	1,256·90(0·0197)	1·6282	1,250·20(0·0170)	1·4840	1,236·00(0·0736)	3·1290	1,231·30(0·0439)	2·3856
Sri Lanka	140·43(0·0020)	0·4177	138·36(0·0016)	1·4227	173·67(0·0571)	2·6646	170·21(0·0217)	1·4888
Thailand	826·38(0·0335)	2·1201	823·88(0·0324)	2·0609	1,040·90(0·1517)	4·4199	1,033·00(0·0892)	3·4681

Notes : (a) Average natural rubber output volume is given in thousand tonnes.
(b) Average natural rubber export earnings value is given in million US dollars
Figures within parentheses denote coefficients of variation of the distribution of values from which the corresponding averages are derived.

Table 3 (c). *Summary of price stabilization effects on major consumers, 1983 — 1995*

Country	Average natural rubber consumption (a)				Average natural rubber consumption expenditures (b)			
	Without stabilization		With stabilization		Without stabilization		With stabilization	
	Volume	Instability index	Volume	Instability index	Value	Instability index	Value	Instability index
France	219 61(0·0117)	1·2990	217·86(0·0126)	1·2709	285·47(0·0874)	3·3857	283·85(0·0508)	2·6358
Fed. Rep. of Germany	191·90(0·0015)	0·4667	190·73(0·0010)	0·3711	248·63(0·0558)	2·6423	250·02(0·0239)	1·7771
Italy	190·44(0·0182)	1·5887	187·90(0·0171)	1·5051	248·91(0·1054)	3·7374	245·47(0·0600)	2·8600
Japan	633·41(0·0371)	2·1855	630·97(0·0368)	2·1559	799·22(0·1620)	4·5372	791·65(0·0955)	3·5981
United Kingdom	155·33(0·0105)	1·1863	153·97(0·0116)	1·1813	201·99(0·0858)	3·2963	200·63(0·0495)	2·5568
United States	978·36(0·0172)	1·5057	970·90(0·0165)	1·4336	1,306·70(0·0982)	3·5587	1,297·20(0·0565)	2·7144

Notes : (a) Average natural rubber output volume is given in thousand tonnes.
(b) Average natural rubber export earnings value is given in million US dollars.
Figures within parentheses denote coefficients of variation of the distribution of values from which the corresponding averages are derived.

First, the simulations show prospective BS operations to be an essential part of successful partial price stabilisation. This arises from the need to consider the lagged effects in a dynamic system. Second, the simulations show that the stabilisation results are critically dependent on the appropriate choice of the reference price. Moreover, the asymmetry in natural rubber supply response to price change, (4) and longer distributed price lags on the supply side than on the demand side of the rubber market are such that more BS purchases than warranted for floor price support are required if the same BS is to be able to defend the ceiling price. The resultant stabilisation becomes, in effect, about non-equidistant price bands. Finally, price stabilisation reduces production and consumption instability for the major countries. While price stabilisation induces income (export earnings) stabilisation, it also provides scope for income transfer from the consuming to the producing countries, albeit in an uneven way.

From the simulation results, two caveats for successful BS operations are in order. These concern prospective BS operations and the INRA constraint on the admissible net change in BS volume within 18 months.

The efficacy of the prospective BS purchases/sales is contingent on foresight about the behaviour of business cycles and the natural rubber price in future periods. As Fig. 1 shows, the level and stability of synthetic rubber price has an important influence on the level and volatility of natural rubber price. This role of synthetic rubber price could therefore be explicitly incorporated into the INRA clauses governing price revisions so as to enhance the automaticity of the price revision rules. The importance of foresight for successful stabilisation highlights the critical reliance on the judgement and ability, to take timely action, of the BS manager. As Nurkse (1958) and Benoit (1959) have indicated, BS operations could result in investing excessive arbitrary authority on the BS manager.

In all the simulations reported, the constraint of net change in BS not exceeding 100,000 tonnes within 18 months was binding. In the case of *ex post* simulations, the constraint was binding in 1971 and 1975 when price support was necessary. Similarly, the *ex ante* simulation indicates that the constraint will be binding because of the consecutive support buying in 1987 and 1988. In practice, the constraint became binding only 4 months after the initial BS buying began and an INRC meeting had to be convened in March 1982 to lower the reference price and stabilisation price bands. By September 1982, only 19 months after BS began, the net change in BS had reached 200,000 tonnes and an INRC meeting had to be convened again. This experience, together with the simulations results presented in this paper, suggest relaxing the constraint on net BS change within 18 months to about the 200,000 tonnes level. In addition to reinforcing the efficacy of the BS purchases, this relaxed constraint would also reduce the need for frequent and costly renegotiations.

In concluding, it is interesting to mention that the problem of the distributed lagged price effects for INRA is similar to that for the International Tin Agreement which Smith and Schink (1976) had ascertained. The simulations have shown that it is these lagged

(4) This asymmetry stems from the nature of rubber production. When price remains too low, tapping of the tree and hence production can be stopped instantly. However, when price increases sharply, output can be increased only in so far as slaughter tapping permits, assuming that all the mature trees are being tapped.

price effects that primarily call for the larger BS accumulation than is permissible under the present INRA. This demand on INRA resources may be reduced if export controls, as is now being suggested, are introduced as an additional instrument for stabilisation under INRA. However, the implementation of export controls without concurrent production controls would mean imposing an additional burden on governments to hold national stockpiles and therefore reduce the gains from stabilisation to the producing countries. If production controls are concurrently introduced, then the problem of further distorting the supply response will have to be considered.

APPENDIX

Main features of the rubber model used in simulating INRA

The rationale for the joint modelling of the natural and synthetic rubbers market stems from their joint derived demand. In the last two decades, about 65 — 70 percent of this stems from the production of tyres, tubes and automative parts for the transport sector. The remaining 30 — 35 percent of demand derives from the production of producers' goods such as conveyor belts to consumers' goods such as footwear and gloves. This joint demand gives rise to substitution, and hence competition, between the two types of rubber.

In tyre production, there exists minimum requirements of each type of rubber input so that input substitution due to relative price changes occurs only in the range beyond these minimum requirements. However, adjustment costs and the known volatility of natural rubber price delimit the extent of price-induced substitution in the short run. In the former, adjustment costs incurred could offset savings from input substitution. This is reinforced by the natural rubber price instability which restrains prompt substitution whenever prices change. Consequently, substitution occurs gradually after the relative price change is perceived as sustainable.

Assuming cost minimization, the input demand functions takes the following forms

$$CN = f_1 \{ (PN/PS), (PN/PS)_{-1}, \ldots, (PN/PS)_{-n}, Q, T \}$$

$$CS = f_2 \{ (PN/PS), (PN/PS)_{-1}, \ldots, (PN/PS)_{-n}, Q, T \}$$

where CN and CS are the consumption of natural rubber and synthetic rubbers respectively, (PN/PS) is the relative price of natural rubber to synthetic rubbers, Q is the production of rubber goods (such as tyres and tubes in the transport sector) and T is a trend variable to proxy technological change in production. The presence of the distributed relative price lags reflect the "habit persistence" restraining prompt rubber input substitution upon relative price changes.

Separate equations for rubber input demand by the transport and nontransport sectors were estimated for each of the main consuming countries. Where disaggregated data are absent, a single equation was estimated for each type of rubber consumed.

The differences in their natures of production, marketing and organizational structures call for different approaches to the modelling of natural rubber and synthetic rubbers supplies. Natural rubber is a perennial crop produced under conditions approximating perfect competition. In contrast, synthetic rubber is a manufactured product based on petrochemical feedstocks. Furthermore, the industry is vertically integrated to a large extent, backwards with the petrochemical industry and forwards with the tyre industry. Hence the industry operates under imperfect competition.

The problems of modelling the supply response of perennial crops are well known and stems from the long gestation and productive lifespan periods which introduce long lagged effects into the system. To date, one of the more sophisticated models on perennial crop supply is that by Wickens and Greenfield (1973) which takes into account the investment feature of perennial crop supply. Adopting the Wickens and Greenfield approach, the supply of natural rubber was estimated in the following form from first-differencing of the reduced form :—

$$q_t = \sum_{i=o}^{k} \tau^*_i \, p_{t-i} + (1 + \lambda)\, p_{t-1} - \lambda q_{t-2} \qquad (3)$$

where q is natural rubber supply, P is the price of natural rubber, and k is the number of lags which typically extends from 10 to 14 years. The coefficient τ^*_i is a composite function of (a) the yields of trees of various ages, and (b) the price coefficients of different periods which goes to determine the output response (Wickens and Greenfield, 1973).

The equations for natural rubber stocks and spot price formation are based on the hypothesis that price formation is due to disequilibrium demand for stocks in the consuming regions. Since the data for stocks located in the consuming regions are unsatisfactory, it was decided to estimate the price equation directly. The spot price equation is written as :

$$(PN^s/WPI^{uk}) = f \left\{ \Delta + (SNC/CN),\ \Delta SNG,\ (PN^s/WPI^{uk})_{-1},\ (PN^s/WPI^{uk})_{-2},\ DV(1),\ DV(2),\ DV(3) \right\} \qquad (4)$$

where PN^s is the London spot price, WPI^{uk} is the UK Wholesale Price Index, $\Delta(SNC/CN)$ is the change in the ratio of stocks in consuming regions to total consumption, ΔSNG is the change in government stockpiles, DV(1) is a dummy variable for the racial riots in Malaysia in 1969, DV(2) is the dummy variable for the oil crisis in 1973/74, and DV (3) is the dummy variable for the 1973 recession and the peak of the Malaysian "Crash Programme" of production controls to prevent further price declines.

Stocks held in the producing countries (SNP) and afloat (SNA) are assumed held for precautionary reasons, and are estimated together in the form $(SNP + SNA) = f \{ \Delta (CN/QN), (SNP + SNA)_{-1} \}$ where $\Delta (CN/QN)$ is the change in the ratio of total consumption to total production. Thus, as this ratio increases, more stocks will be shifted from the producing regions and afloat to the consuming regions. The stocks in the consuming regions are then treated in the balance equation.

The modelling of synthetic rubber supply is based on the dependence of the synthetic rubber industry on the oil industry for its raw material inputs and on the tyre industry for the bulk of its demand. The upshot of these interrelations is the observed vertically integrated oligopolistic structure of the industry which facilitates intra-firm pricing and price discounting. Such closed trading also harbours the synthetic rubber industry to some extent from the general market instabilities.

Assuming cost-plus pricing for synthetic rubber, the average price of synthetic rubbers (PS) is determined by the average cost of synthetic rubber production and the level of mark-up per unit of synthetic rubbers sold. As the general-purpose synthetic rubbers compete with natural rubber, the mark-up is hypothesized as being determined by the level of natural rubber price (PN). Since the average cost consists of average fixed costs (which in an industry with scale economies is determined by the production capacity CQRS) and average variable cost (which is dependent on the price of raw material inputs, chiefly oil) the average synthetic rubber price is given by :

$$PS = f_4 \{CQSR, P^{oil}, PN\} \tag{6}$$

where P^{oil} is the price of oil.

Similarly, synthetic rubber supply is some form of

$$QSR = f_5 \{CQSR, P^{oil}, PN\} \tag{7}$$

The model is closed with balance equations for the stocks of natural rubber and synthetic rubbers. In addition, there are several price linkage equations, linking natural rubber prices in the primary and terminal markets to the London spot price, and linking various countries' synthetic rubber prices to the average synthetic rubber price that is estimated.

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COMPLETING THE CENTURY: LONG RUN PRODUCTION CYCLES AND THE SRI LANKA RUBBER INDUSTRY OVER THE NEXT 25 YEARS

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ABSTRACT

Data collected for the Rubber Industry Master Plan Study are used to examine the implications of alternative replanting strategies for the productive capacity of the rubber industry over the next quarter of a century. Five strategies are simulated, including one based on farmers declared intentions. The starting year for the simulations is 1978 so that it is possible to begin to trace the beginnings of the most likely path. It is concluded that Sri Lanka's rubber output will decline until about 1998 before commencing to increase. The study also suggests that there is a substantial gap between productive capacity and actual output levels.

INTRODUCTION

All tree crops have certain features in common, irrespective of whether their commercial product is fruit, fodder, building material, firewood or an industrial raw material. Like man, trees take time to mature and usually live from one to many decades. The rubber tree is unique among the important tree crops in that the current techniques used to obtain the main product results in the gradual destruction of the tree. We might say then that the process of rubber production involves the deliberate killing of the tree by the necessity of ring barking it.

For an individual tree of a particular clone, in a given environment on a given soil, the current flow of production is determined by the age of the tree, how well it has been maintained, the rate at which its bark has been removed and the rate at which it is currently being removed. For a particular farmer (estate, country), the current flow of rubber production is determined by the existing stock of trees of each clone of different ages multiplied by the clone/age specific yields. Thus current output is constrained by past planting and exploitation decisions. In the same way future output will be constrained by present planting and exploitation decisions.

A baby boom in a human population results in a cohort ' bulge ' that gradually works its way up the demographic pyramid. In so doing it has ramifications on demand patterns, incomes and dependency ratios. In parallel fashion planting booms in tree crops work their way up the age profile with implications for production and processing. To change the analogy, we might say that past planting decisions throw their ' waves ' into the future and it is important for marketing and national planning policy to be able to forecast such long run cyclical patterns.

The purpose of this paper is to demonstrate the methodology of forecasting and to examine the future ' waves ' of the past planting decisions of the Sri Lankan rubber industry. In particular we shall focus on the implications of alternative rates of replanting and derive their impact on future rubber production.

In undertaking an exercise of this nature it must be understood that we are concentrating on the long run implications of past activities. Annual deviations from these trends are expected due to fluctuations in climatic conditions and in the response of producers to current market prices. The crucial policy perspective is that the long run trends themselves cannot be avoided without radical changes in the technology of exploiting the rubber tree.

After describing the sources of data in the next section, the following sections first examine the rubber area and intensity of exploitation then suggest five alternative replanting strategies. Projections based on these are given in Section V and production scenarios are presented in Section VI. The final section compares the results with other studies and presents some overall conclusions.

Data sources

The data used in this analysis were collected from two sources. The first was the Annual Administrative Report of the Rubber Controller from which data on area, production and prices were obtained. Data on the immature and mature bearing areas were not presented in a manner that allows one to make projections of the future area.

The second source of data was the Rubber Industry Master Plan (RIMP) Study (1979) of Sri Lanka. Unlike the Rubber Controller's data sources, this is a cross-sectional survey carried out in 1978, to investigate age -specific area, bark consumption, the remaining life of the trees and their general condition. With the encouragement of the Rubber Research Institute, the Commonwealth Development Corporation, who conducted the survey, released to us 1305 questionnaries relating to over 13000 individual holdings selected on the basis of a stratified random sample using a set of aerial photographs as the sample frame.

The major problem encountered in the RIMP Survey data was in using sample parameters for estimating population parameters. The lack of clarity in the text of the final Survey report and the fact that the ground survey and area estimates were not directly linked with each other created difficulties for further analysis. As a result in some areas sample strata had to be added using ' best guess ' weights, based on the significant rubber areas. The other main limitation the RIMP Survey was the lack of information on stock depletion which occurs as a consequence of extraneous weather conditions, disease, and deliberate decisions made by farmers to uproot or abandon the old rubber trees.

In addition to these two main sources of data, data given by the Rubber Research Institute of Sri Lanka was also examined. Since these data are also based on the Rubber Controller's data, no significant difference could be observed between them.

Rubber area and exploitation

At the end of the 1970s, the total rubber area in nine main rubber growing districts of Sri Lanka was estimated by the aerial photographic analysis of the Rubber Industry Master Plan Study (1979) to be 210,465 hectares +/- 4 per cent. This figure is below the figure given by the Rubber Controller (226,400 hectares) but is close to the estimates provided by the Agricultural Census (1972/73) and Agricultural Productivity Committee Survey (1973), with figures of 205,800 ha and 209,800 ha respectively. The total rubber area, estimated from photographic analysis by the Rubber Industry Master Plan Study, is broken down by districts and given in Table 1.

Table 1. *Total rubber area*

Districts	Estimated rubber area (ha)	Percentage of Total
Kalutara	42,400	20·3
Kegalle	61,400	29·4
Ratnapura	38,100	18·3
Colombo	31,400	15·0
Galle	15,700	7·5
Matara	7,600	3·6
Kurunegala	5,900	2·8
Matale	2,800	1·3
Kandy	3,400	1·6
Total	208,700	100·0

Source: Report on the Rubber Industry Master Plan Study — Volume V. Economic Studies — September 1979 — Page (ii) of the Summary.

It has been estimated that large areas of marginal land were withdrawn from rubber production during the 1960s and 70s. Due to the high prices of rubber in the immediate post war period, some of the rubber plantations were exploited very intensively. On the other hand, rubber areas were abandoned in the following period of lower prices. The substantial reductions in 1962 and 1981 of the estimate of the total rubber area suggests an underlying downward trend that has been obscured in the annual data (see Table 2).

If senile rubber stands are not abandoned or withdrawn from rubber production, they must be replanted. Replanting of rubber is a major investment, especially for smallholders. In addition to the finance required to clear and replant the land, there is also the loss of income during the immature period of the new cycle. Although intercropping can bring additional income during this period, it has not been practised on any great scale. This perhaps is largely due to lack of capital for initial investment in intercrops, coupled with factors such as uncertainty of markets, labour constraints and the prevalence of theft. Furthermore, there has not been any active encouragement of intercropping and demonstrations have not been widespread.

An accelerated replanting scheme was started in 1953. The success of the replanting subsidy program in exceeding the target of 75,000 acres (30,350 ha) for the first five years is evident in Table 2. 93,978 acres (38,038 ha) were replanted or planted in this period. However from 1963 until the end of the 70s the rate of replanting fell to unsatisfactory levels, in the sense of being well below the target of 6,070 ha a year.

Table 2. *Area replanted 1945 — 1978 (ha.)*

Year	Total area	Replanted area Total	S. H.	M.H.	Est	New planted area	Replanted area as a percentage of total area
1945	267126	38	na	na	na	1104	0·02
1946	267025	666	na	na	na	613	0·25
1947	266794	857	na	na	na	183	0·33
1948	266538	592	na	na	na	119	0·23
1949	265226	890	na	na	na	232	0·34
1950	265273	1565	na	na	na	272	0·59
1951	265385	1387	na	na	na	570	0·53
1952	265943	1700	na	na	na	553	0·64
1953	266165	2348	188	400	1780	348	0·89
1954	266886	7472	1588	2075	3809	619	2·80
1955	267605	8464	2270	2484	3710	502	3·17
1956	267500	9809	2757	3029	4024	1130	3·67
1958	269184	8355	2650	2357	3348	935	3·11
1959	270517	7503	3150	1848	2504	813	2·78
1960	270829	7244	2911	1837	2495	786	2·68
1961	271591	7565	3106	1674	2807	572	2·79
1962	229684	7269	2831	1413	3004	277	3·17
1963	229952	6442	2489	1090	2863	268	2·81
1964	230123	5487	1985	1559	1942	171	2·39
1965	230384	5061	1956	1284	1821	260	2·20
1966	230540	4689	1968	863	1866	157	2·04
1967	230413	4083	1337	858	1888	55	1·78
1968	230448	5155	1734	953	2470	237	2·24
1969	230228	4892	1665	707	2520	126	2·13
1970	230178	4145	1430	691	2023	112	1·80
1971	229953	3431	1207	553	1672	238	1·50
1972	229655	3539	951	448	2139	180	1·55
1973	228673	2946	930	374	1641	186	1·29
1974	228100	2865	986	338	1540	34	1·26
1975	227730	3230	1128	520	1582	142	1·42
1976	277074	2550	1132	317	1102	56	1·12
1977	226660	2617	1196	313	1107	45	1·15
1978	226400	3225	1415	320	1490	378	1·42
1979	226300*	5381	1548	3833		582	2·37
1980	227300*	5333	2240	3193		977	2·39
1981	205600*	6442	3579	2863		1055	3·13
1982	205700*	6376	5224	1152		1650	3·10

Source : Department of Rubber Control, Sri Lanka. Central Bank of Ceylon, 1978 and 1982*

The rubber replanting subsidy scheme is operated with the aim of achieving a replanting cycle of 33 years. This would require that about 3 percent of the total area under rubber be replanted annually. For fifteen years ('64 — 78) this target was not achieved, suggesting an ageing national rubber plantation. In fact the RIMP Study showed that 44 percent of trees had between 0 and 9 years' life remaining (RIMP Study, 1979 : p. 7). The registers of the Rubber Controller for the same year showed about 89,070 ha of overage rubber, representing about 40 percent of the crop area.

In order to remedy this situation and on the recommendation and with the funding of the FAO and World Bank (FAO — World Bank, 1979), the government of Sri Lanka in 1981 implemented a smallholder rubber replanting project. The resultant sharp increase in replanting since then is shown in Table 2. The Table also indicates the fluctuations in the replanting rates. These fluctuations cause the 'waves' that are the main focus of this study.

The rate of rubber replanting is to a large extent a reflection of the economic decisions taken by the thousands of farm households. The long term investment decision of rubber replanting cannot be separated from a multitude of other decisions, both short-term and long-term, made by farmers. The decision to replant a particular rubber stand, plant up a new area or choose another crop takes place in the normal course of attempting to maximize some form of a multi-period utility function. While the variables in such a function include non-economic factors, economic considerations are likely to be crucial for rubber is, after all, grown as a *cash* crop. The theory of optimal replacement was set out by us at the last International Rubber Conference in this venue (Etherington and Jayasuriya, 1976) and does not need repeating here. In practical terms the replacement date is decided upon by the past rate of bark consumption and the anticipated average annuity of returns from the new stand of trees.

Using sample data collected by the RIMP Survey on the rate of bark consumption and the estimated remaining life of the trees we calculate a simple index of the intensity of exploitation. Although the remaining life of the trees is a highly subjective judgement, it does give an important assessment on the future life of the national rubber plantation. On the basis of the supposed standard replanting cycle of 33 years, the index of the intensity of exploitation (INTEX) is simple :

$$\text{INTEX} = 33/(A + R) \times 100$$

where A = Age of trees

R = Remaining life of trees

Table 3 gives the frequency distribution of this index for the 12 thousand hectares of rubber in the RIMP sample. The Table shows that the intensity of exploitation is equal to or below 100 percent only in 15·3 percent of the rubber area. This area is a reflection not of undeveloped trees, but of areas of proper bark consumption which have a reasonable age and remaining life.

The estimate of the remaining life of the trees was calculated with reference to the rate of bark consumption. High consumption of bark while a tree is young reduces the remaining life. If this happens frequently, the 'age' plus the 'remaining life' is below 33. This is reflected in the Table 3 where intensity of exploitation is greater than 100 percent. Thus 84·7 percent of the total area falls into this category. However it is important to note that there are some areas of rubber which go out of production or prematurely 'die' due to pests and diseases and climatic factors. Such areas are not very significant, but it could be a minor reason for the intensity of exploitation being above 100 percent. The age distribution of the national rubber estate is based on the relative frequency distribution presented in Table 3. In the RIMP Survey this frequency distribution distinguishes between smallholders and estates. Unfortunately, however, inconsistencies found in the survey data prevented the undertaking of regional analyses and it was only possible to build up a national-age distribution accounting for 171 thousand hectares (85%) out of the survey's estimated total of 208 thousand hectares. Again, while the impression given by Table 2 is one of basic stability in the size of the area under rubber, the need for major periodic downward adjustments suggests that the official records are not entirely satisfactory and belie an underlying downward trend of between 0·5 and 1 percent per annum. In spite of these difficulties with the data, it seems to us valid to proceed with an analysis of the cyclical fluctuations in area and output as an illustration of this method of forecasting.

Replanting strategies

Given the, admittedly weak, estimates of the size and age distribution of the national rubber 'estate' a set of five purely mechanistic 'demographic' replacement models are applied to the data. The models are mechanistic in the sense that three of them do not allow divertions from deterministic cohort or vintage replacement cycles. This changes in the relative price of rubber are assumed to have no impact, yet we know that historically the Sri Lankan rubber industry has responded to high prices (Herath, 1975) by increasing the intensity of exploitation, raising output and, consequently, altering the length of the replacement cycle.

Using the year of the RIMP Survey as the fulcrum, five replacement strategies are applied to the national estate : 'stepping back' through time as a means of validating the procedure and then 'stepping forward' in a predictive manner. The five strategies examined are :

(a) a 26 years replanting cycle ;
(b) a 30 years replanting cycle ;
(c) a 33 years replanting cycle ;
(d) a 3 percent of the area replanting per annum ;
and (e) a replanting policy based on farmer's expressed intentions to replant.

The first three strategies are based purely on the age of the plantation, that is every 26, 30, or 33 years the rubber trees are all replanted. The first two cycle lengths were selected on the basis of the analysis done by Jayasuriya (1973) on the optimal replacement age under varying assumptions regarding tapping systems, discount rates, technological change, subsidy, and prices. These studies and the evidence of Table 3 show that optimal cycle lengths are typically less than 33 but more than 25 years. Nevertheless, the selection of the 33 years policy is particularly important since the current official rubber replanting scheme operates within an implied replacement cycle of this length. This has been the accepted 'rule of thumb' of the rubber industry.

Table 3. *Intensity of exploitation (INTEX) of rubber*

Length of replanting cycle (Years)	INTEX %	Absolute frequency (Sample ha.)	Relative frequency %	Cumulative frequency %
78	46	24	0·2	0·2
53	62	1	0·0	0·2
51	65	15	0·1	0·3
47	70	13	0·1	0·4
46	72	15	0·1	0·6
44	75	35	0·3	0·9
43	77	25	0·2	1·1
42	79	50	0·4	1·5
39	85	100	0·8	2·3
38	87	54	0·5	2·8
37	89	221	1·8	4·6
36	92	137	1·1	5·8
35	94	432	3·6	9·4
34	97	306	2·5	11·9
33	100	406	3·4	15·3
32	103	583	4·9	20·1
31	106	2532	21·1	41·2
30	110	1586	13·2	54·4
29	114	2511	20·9	75·4
28	118	576	4·8	80·2
27	122	439	3·7	83·8
26	127	317	2·6	86·5
25	132	1310	10·9	97·4
24	138	107	0·9	98·3
23	143	135	1·1	99·4
22	150	37	0·3	99·7
21	157	9	0·1	99·8
20	165	25	0·2	100·0
19	174	1	0·0	100·0
12	276	1	0·0	100·0
	Total	12003	100·0	

While a crop cycle of 33 years implies 3 percent annual replacement, a major distinction must be drawn between a cycle based on age and one based on a percentage of the area planted. In the former case the annual replanted area depends critically on the cohort structure of past planting. In the latter case, the annual replanting depends only on the total area under rubber and not on the age structure of the trees. The rubber industry planners in Sri Lanka have not faced up to this fundamental distinction since alarm is expressed whenever the replanting falls below 3 percent with no discussion as to whether this is simply because 33 years earlier fewer trees had been planted and/or replanted. An age-specific replanting policy will only match a corresponding ' percentage-of-area ' policy, if the latter policy is in fact implemented every year.

The final strategy under investigation is probably the most realistic since it is based on responses to a RIMP Survey question regarding the replanting intentions of the rubber farmers. Clearly the intentions of farmers are crucial in replanting policy decisions. The most significant aspect of this procedure is its capability to capture both the 'infant' and 'juvenile' mortality of the trees. In reality whatever the replanting strategy adopted, it is also important to consider the premature 'death' of trees due to wind, drought, excessive rains, disease or pests.

Table 4, which is based on the survey results, bears out the contention that replacement should be viewed as a probability distribution rather than a deterministic fact (Etherington 1977). The cumulative distribution shows that 14·1 percent of replacement is premature in the sense that removal has taken place at ages less than that normally considered to be economic (*i.e.* 25 years). A further 6·9 percent are allowed to continue into 'old age' (over 37 years) and 3·9 percent into 'senility' (over 48 years).

One simple method of validation is comparison of each model output with the available historical records. The logic behind the procedure is to go back to the past in the same way and under the same policy that future values are simulated. This has a dual purpose. First, it validates the model by comparing it with past records. Second, it allows the selection of the most accurate replanting strategy for future prediction purposes. It is presumed that the correct policy for future prediction is the one which gives past values closest to the actual records.

In general the results of the validity tests of the models over the period 1950 — 1978 were not very good. The best regression result was using Strategy 5 with a coefficient of determination (R**2) of 0·583. (The other strategies ranged from 0·247 for strategy 2 to 0·315 for strategy 1). Rather better results were obtained comparing actual and predicted past *output* of strategy 5 with a 3 year moving average to smooth out annual fluctuations due to weather and other random influences. In order to obtain the predicted output figures, predicted areas were multiplied by the yield coefficients to be presented later. The two distributions are presented in Table 5. The coefficient of determination between these time series is 0·949 with a slope coefficient of 1·097 and an intercept of - 12505·7, indicating almost a 1 : 1 correspondence.

Model experimentation and projections

In a real sense it is not particularly important whether any of the five strategies presented in the previous section accurately 'predict' the past if they are in fact applied in the future. Whatever strategy or group of strategies applied in the past, if from the pivot date of 1978 everybody *actually* adopted a 33 year cycle, then *future* replantings are completely predictable. Thus, given an initial (1978) age distribution of the total area, any strategy can be mechanistically applied to generate successive cohorts or vintages while retaining a constant total area.

The computer simulations of the age distribution of the total rubber area under each of the five strategies are presented in Appendix Tables A. 1 to A. 5. With the first 3 strategies it is assumed that the area older than the strategy cycle length is 'senile' and is replanted in the first year. In the case of strategy 4 the issue does not arise while for

Table 4. *Frequencies of intended removal age*

Age	Sample frequency (ha.)	Relative frequency	Cumulative frequency
0	81	0·586	0·586
1	0	0·000	0·586
2	1	0·007	0·593
3	27	0·195	0·688
4	1	0·007	0·695
5	0	0·000	0·695
6	61	0·441	1·136
7	1	0·007	1·143
8	1	0·007	1·150
9	12	0·087	1·237
13	3	0·021	1·258
15	19	0·137	1·395
16	1	0·007	1·402
17	0	0·000	1·402
18	5	0·036	1·438
19	1	0·007	1·445
20	40	0·289	1·734
21	11	0·079	1·813
22	52	0·376	2·189
23	135	0·976	3·165
24	129	0·932	4·097
25	1385	10·014	14·111
26	320	2·314	16·425
27	488	3·528	19·953
28	587	4·244	24·197
29	2517	18·200	42·397
30	1657	11·981	54·378
31	3118	22·545	76·923
32	664	4·801	81·724
33	446	3·225	84·949
34	306	2·213	87·162
35	469	3·391	90·553
36	137	0·991	91·544
37	221	1·598	93·142
38	215	1·555	94·697
39	120	0·867	95·564
40	68	0·492	96·056
41 & above	533	3·944	
TOTAL	13830	100·000	100·00

Source : RIMP Survey Data.

Table 5. *Comparison of three year moving averages of model output and actual production*

Year	Actual (metric tonnes)	Model
1953	107000	104795
1954	102200	109340
1955	98000	103679
1956	96000	105970
1957	98000	107145
1958	100000	110403
1959	99000	102310
1960	98000	100887
1961	97000	102953
1962	101000	104663
1963	103000	98387
1964	107000	106896
1965	121000	108206
1966	131000	127186
1967	141000	144094
1968	148000	142524
1969	151000	105370
1970	151000	154961
1971	147000	138247
1972	145000	140075
1973	143000	142779
1974	146000	144193
1975	145000	145270
1976	149000	146928
1977	151400	148388

Source : RIMP Study Data and Model output.

Table 6. *Annual replanting area (ha.)*

Year	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5
1978	39528	22333	16800	5141	7911
1979	10726	1499	18	4141	4695
1980	2037	5994	2374	5141	3142
1981	4544	4174	3142	5141	6116
1982	10660	5528	1499	5141	4126
1983	10743	10726	5994	5141	6596
1984	4704	2037	4174	5141	5263
1985	11806	4544	5528	5141	4866
1986	16695	10660	10726	5141	7164
1987	9142	10743	2037	5141	6279
1988	7845	4704	4544	5141	5325
1989	2718	11806	10660	5141	6777
1990	5078	16695	10743	5141	7209
1991	2518	9142	4704	5141	6168
1992	2206	7845	11806	5141	7892
1993	1008	2718	16695	5141	5372
1994	4623	5078	9142	5141	5596
1995	10265	2519	7845	5141	71717
1996	1289	2206	2718	5141	322
1997	4059	1008	5078	5141	3862
1998	1350	4623	2519	5141	6121
1999	1993	10265	2206	5141	6790
2000	1381	1289	1008	5141	4103
2001	249	4059	4623	5141	6895
2002	2804	1350	10265	5141	7761
2003	1400	1993	1289	5141	5002
2004	39528	1381	4059	5141	4744
2005	10726	249	1350	5141	2625
2006	2037	2804	1993	5141	3527
2007	4544	1400	1381	5141	2850
2008	10660	22333	249	5141	3544
2009	10743	1499	2803	5141	3212
2010	4704	5994	1400	5141	4810
2011	11806	4174	16800	5141	6816
2012	16695	5528	18	5141	3505
2013	9142	10726	2374	5141	5007
2014	7845	2073	3142	5141	3835
2015	2718	4544	1499	5141	4355
2016	5078	10660	5994	5141	4216
2017	2518	10743	4174	5141	3826
2018	2206	4704	5528	5141	4952
2019	1008	11806	10726	5141	4410
2020	4623	16695	2037	5141	6765

Source : RIMP Study Data and Model output.

strategy 5 all trees 41 years of age and older are pooled and the relative frequency of intended removals from Table 4 (3.944%) is applied to this area. The results in the Appendix are given for 1978, 1980 and then in 10 year intervals up until the year 2020.

More interesting from a policy point of view are the annual projections of the replanting area presented in Table 6. The data given in Table 6 for the strategy of a 26 years cycle (Strategy 1) seems to be impractical for immediate implementation, since the replanting of 39,068 ha in the first year is impossible. Additionally this strategy implies very low rubber production levels during the immature period of this area. Furthermore, this strategy would necessitate heavy capital investment in one large burst in order to replant such a large area.

The second strategy (30 years cycle) presents a similar problem of impracticability. The initial block of replanting would be over 22,000 ha and this also could only be implemented with a massive replanting programme. However, the one thing in favour of these two strategies is the rapid elimination of the senile area.

The third strategy investigated the implication of the 'official' 33 years replanting cycle. Thus this projection should give a better approximation to reality. The initial replanting of over 16,000 ha is massive but maybe not as impossible as the two previous policies.

The fourth strategy is, according to the rubber policy formulators, meant to be similar to the third. However, it can be seen from Table 6 and the Appendix that it has quite different implications for the rate of replanting. This strategy selects the oldest 3 per cent of the area and replants this amount every year. This replanting target has been set in order to secure the 33 years cycle. Thus, on an assumed total rubber area of 200,000 hectares, policy makers have attempted to relate this policy to the replanting of 6,000 ha. per annum (3 percent of 200,000). However, in reality, the area to be replanted annually is not uniformly equal to 6,000 ha. If the implementation of this policy commences in 1978 and only takes the oldest 3 percent of the area each year it would only match the intended 33 years cycle by 2010 when the total senile area will have been eliminated. In the projections we make, the constant annual replanting of 3 percent is 5,141 hectares per annum.

Table 6 makes it clear that a 3 percent per annum replanting policy will only equate with a 33 year cycle provided the 3 percent policy is adhered to every year. In general a 33 years exploitation cycle (or any age specific cycle) will always reflect the cohort/vintage history of previous plantings and replantings.

The area replanted under Strategy five is also presented in Table 6. Whatever government policy is, the real situation will deviate from it according to the farmer's behaviour. The advantage of this strategy is its likely closeness to reality, which was demonstrated by the validation procedure.

Total production under different strategies

The rubber production potential is to a large extent predetermined by the yield profile of the trees that are already being exploited. Standard yield curves have been constructed by the Rubber Research Institute of Sri Lanka (RRISL) and the Association of National

Rubber Producing Countries (ANRPC) for the area above and below 40·5 hectares. The yield curve of the ANRPC is largely based on the yield pattern of PB 86 taking the average of various clones into consideration. The yield curve of RRISL is also based on the yield of PB 86 over 16 years of tapping in large scale experiments.

Both curves are based on a 33 year replanting cycle. In this study these yield curves have to be modified to fit the length of each replanting cycle. The yield of a particular age in a shorter cycle is of course higher than in an longer cycle. Further, yields are assumed to differ between estates and smallholdings with the former having higher yields. In addition, for the future, it is also assumed that the new plantings will be high yielding varieties and together with the application of fertilizer and stimulants will give better yields. The yield curves related to the five strategies and the one based on a hypothetical yield assuming future improvements in technology are presented in Appendix Tables B1 and B2.

Rubber production is determined by the mature area and the yield curve. The area prediction made previously and the yield curves mentioned in this section are used together to work out the production *capacity*. The following equation gives formal expression to the approach adopted :

$$Q(t) = E\ a\ (i).\ X(i, t)\ +\ E\ b\ (i)\ \cdot 2\ (i, t)$$

where Q(t) is the production capacity in year 't'

a(i) and b(i) are the yield levels of one hectare of rubber in the 'i' the year of tapping for smallholders and estates respectively.

X(i,t) and Z(i, t) are the areas, in hectares, in their 'i' the year of tapping in year 't'.

The results are summarised in Fig. 1. The overall pattern clearly demonstrates the long run cyclical fluctuations caused by the cohort structure and the age/yield relationship.

Rubber trees planted during the first half of the 1978's will come into bearing towards the end of the same decade and will reach maximum yield at the end of the next decade. Therefore the action that will be taken with respect to replanting and new planting today will have an impact, in terms of incremental production, in the mid-1990's. This pattern can be recognized from the projected production given in Fig. 1 and Appendix Table C1. Under Strategy one, the replanted area will only come into bearing the latter part of the 1980's and full impact will not be felt until the mid 1990's. Gradually production begins to decrease again at the beginning of the 2000's. Generally with a shorter replanting cycle, high yields are obtained in the early years hut the trees also go out of production early. Since the cycle is a little longer in strategy two, the impact of the newly planted area will come later. The full impact on increased production of the initiation of this policy will be felt in the latter part of the 1990's. However, in strategy 3 the full impact of the strategy only starts from about the year 2000. Strategy four results in a constant amount to be replanted each year since it is based on 3 percent of a total area which is

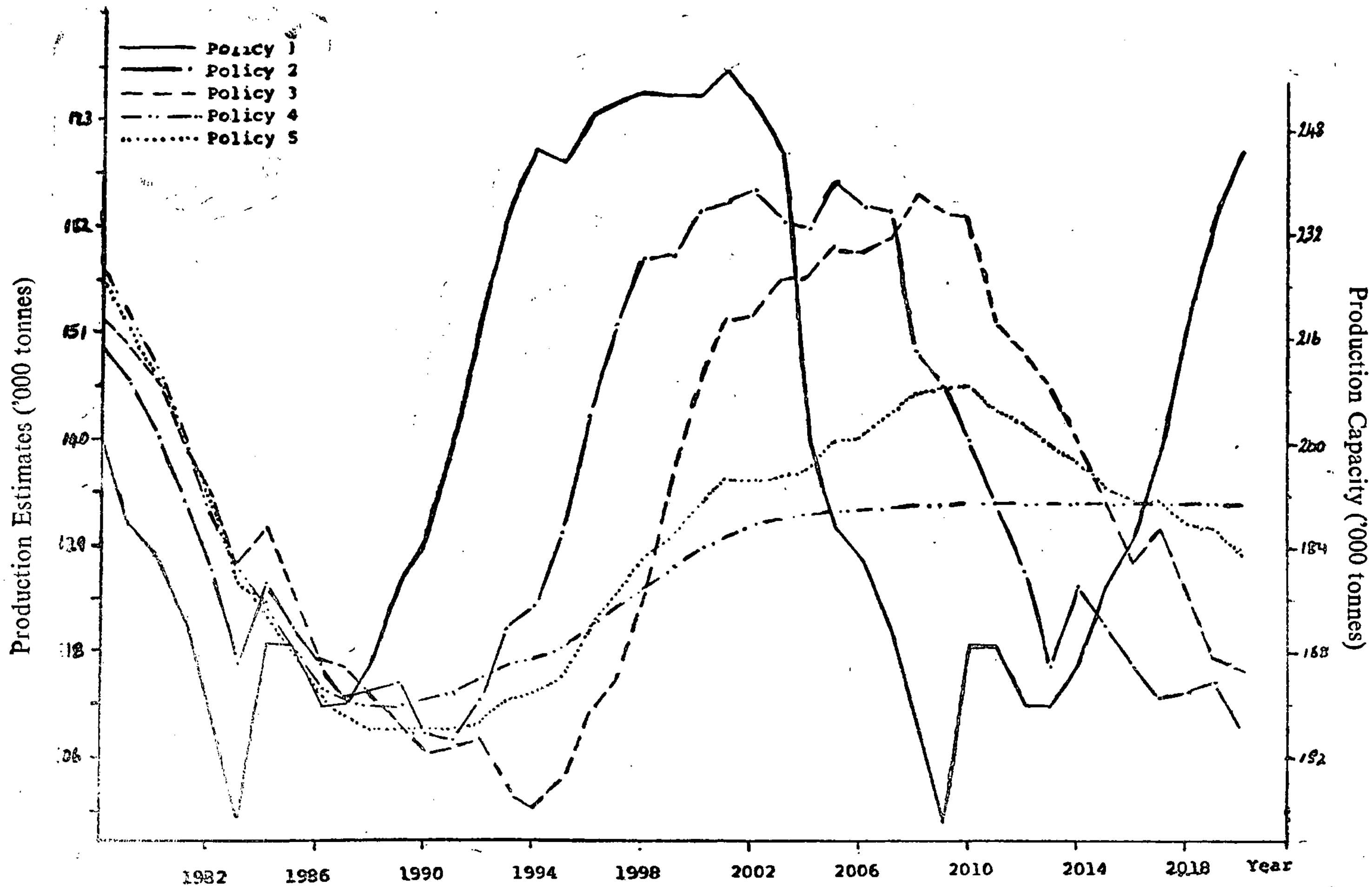

Fig. 1. Production capacity & production of rubber under 5 strategies.

itself fixed by assumption. Although the area replanted each year is constant the age structure of the total area at the beginning of the strategy is variable so that recovery to constant production levels of about 190,000 tons is not achieved until the next century. The production 'strategy' five is expected to be closest to reality.

The projections of production presented here are simply aimed at quantifying the output norms or the productive capacity up to the year 2020. A comparison of Table 5 and the projection of productive capacity in Fig. 1 (& Appendix C1) show a major discontinuity. This implies that all the projections grossly overestimate current and possibly future yields. However, even if the levels of *output capacity* are optimistic, the *cyclical pattern* will remain. To provide direct comparability to actual production levels, we present an alternative scale on the left hand side of Fig. 1. This scale represents a shift downwards of 30 percent and is an informed guesstimate on our part. Irrespective of the model chosen a major decline in Sri Lankan rubber production is predicted to occur between the starting date of 1978 and 1990. Using Model 5 as the most likely scenario, the prediction is for increasing output from about 1995 for about 15 years (to 2010) when the long run cycle will start to repeat itself.

Comparisons and conclusions

The comparison of our projections of output capacity with other projections of output is informative and is given in Table 7. It can be seen that the projections give quite different estimates. A major difference between our projection and the others is the decline in production up to about 1995.

Table 7. *Comparison of results of different sources*

Year	Model output	RRISL(1)	ANRPC (2)	World Bank (3)	Smit (4)
		(thousand metric tonnes)			
1980	210	173	180	180	165
1985	168	169	193	185	165
1990	156	172	174	195	180
1995	164	201	—	—	195
2000	191	245	—	—	210

Source : 1. Rubber Research Institute of Sri Lanka, 1979.
2. The Association of Natural Rubber Producing Countries, 1976.
3. World Bank/FAO, 1978.
4. Smit, 1981.

Our predicted values from Model 5 are based on the expressed intentions and expectations of the rubber farmers/planters in 1978, prior to any recommendations or proposals under the Rubber Industry Master Plan. It is therefore interesting to compare declared intentions with actual replanting in the period 1978 to 1982. Actual replantings have been 26,857 hectares as against a declared intention of replanting 25,990 hectares. This suggests that the scaled output projections should be taken seriously. In particular, the relatively low levels of output during the next ten years should be noted. A recent study of the National Planning Division of the Ministry of Finance and Planning (Public Investment Report 1983 — 87, May 1983) comes to a similar conclusion regarding these trends when they say that 'if the replanting programme continues . . . production will decline to a low of 100 (thousand metric tons) by 1986 and then commence increasing rapidly as the replanted acreages mature, regaining the 1978 peak of 158 (thousand metric tons) by 1995, (para. 4.48). Our estimate is for a slightly longer trough with a new peak occurring well after the turn of the century. Actual output figures since 1978 and our scaled projections read as follows :

Year	Actual output	Scaled projection
	(thousands of metric tonnes)	
1978	155	157
1979	152	151
1980	133	147
1981	124	140
1982	123	134
1983	126*	129
1984	—	123
1985	—	118

Source : Central Bank of Ceylon (1983) *Estimate

Two conclusions stem from this analysis : first, many of the projections of Sri Lanka's rubber output do not take adequate account of the long run cyclical fluctuations caused by past bursts of planting and replanting activity ; secondly, there is a very considerable gap between output projections based on idealised yield curves and the yield levels actually achieved. Our 30 percent adjustment is admittedly somewhat arbitrary but it highlights the major discrepancy between actual rubber yields and those suggested as likely by the RRISL. The RRISL yield estimates are modest while the hypothetical yields we give are not unreasonable. The International Rice Research Institute (IRRI) has made detailed investigations into the 'constraints' which prevent farmers achieving either experimental yields or those of better farmers. Clearly a 'yield gap' of 30 percent is well worth exploring and it suggests that there may be very substantial returns to Sri Lanka from improvements in the effectiveness of the extension service — especially to the smallholders who, because of their current low yield levels provide the greatest potential source of increasing output above historic levels.

This paper has used data on the age distribution of the Sri Lanka rubber plantings collected by the RIMP Survey (1978) and has used this to generate forecasts of rubber production based on alternative replanting strategies. The mechanistic application of these replanting strategies result in the long-term cyclical recurrence of planting (replanting) booms. The results suggest that rubber output levels will decrease steadily over the next ten years before starting to recover. Such projections do not take account for short term fluctuations caused by weather or responses to changes in producer prices. This is the main drawback of this simulation procedure. It simply assumes that the natural rubber prices will remain high enough to continue rubber production and consistent replanting. Unless the future is very different from the past, prices will deviate around the trend and cause variations in the intensity of tapping and in the use of the other inputs and, therefore, actual output levels are likely to deviate from these projections.

Note: References were not included in the original manuscript.

APPENDIX

Table A 1. *Total rubber area under Strategy 1 (ha.)*

YEAR

	1978	1980	1990	2000	2010	2020
0	39528·809	2037·469	5077·877	1381·548	4703·781	4623·044
1	1399·600	10726·425	2717·963	1993·340	10743·476	1007·953
2	2803·714	39528·809	7845·485	1350·456	10660·231	2206·464
3	248·729	1399·600	9141·782	4059·393	4543·812	2518·880
4	1381·548	2803·714	16695·412	1289·277	2037·469	5077·877
5	1993·340	248·729	11806·088	10265·073	10726·425	2717·963
6	1350·456	1381·548	4703·781	4623·044	39528·809	7845·485
7	4059·393	1993·340	10743·476	1007·953	1399·600	9141·782
8	1289·277	1350·456	10660·231	2206·464	2803·714	16695·412
9	10265·073	4059·393	4543·812	2518·880	248·729	11806·088
10	4623·044	1289·277	2037·469	5077·877	1381·548	4703·781
11	1007·953	10265·073	10726·425	2717·963	1993·340	10743·476
12	2206·464	4623·044	39528·809	7845·485	1350·456	10660·231
13	2518·880	1007·953	1399·600	9141·782	4059·393	4543·812
14	5077·877	2206·464	2803·714	16695·412	1289·277	2037·469
15	2717·963	2518·880	248·729	11806·088	10265·073	10726·425
16	7845·485	5077·877	1381·548	4703·781	4623·044	39528·809
17	9141·782	2717·963	1993·340	10743·476	1007·953	1399·600
18	16695·412	7845·485	1350·456	10660·231	2206·464	2803·714
19	11806·088	9141·782	4059·393	4543·812	2518·880	248·729
20	4703·781	16695·412	1289·277	2037·469	5077·877	1381·548
21	10743·476	11806·088	10265·073	10726·425	2717·963	1993·340
22	10660·231	4703·781	4623·044	39528·809	7845·485	1350 456
23	4543·812	10743·476	1007·953	1399·600	9141·782	4059·393
24	2037·469	10660·231	2206·464	2803·714	16695·412	1289·277
25	10726·425	4543·812	2518·880	248·729	11806·088	10265·073

Source : RIMP Survey data.

Table A 2. *Total rubber area under Strategy 2 (ha.)*

AGE	YEAR 1978	1980	1990	2000	2010	2020
0	22333·430	5994·061	16695·412	1289·277	5994·061	16695·412
1	1399·600	1499·393	11806·088	10265·073	1499·393	11806·088
2	2803·714	22333·430	4703·781	4623·044	22333·430	4703·781
3	248·729	1399·600	10743·476	1007·953	1399·600	10743·476
4	1381·548	2803·714	10660·231	2206·464	2803·714	10660·231
5	1993·340	248·729	4543·812	2518·880	248·729	4543·812
6	1350·456	1381·548	2037·469	5077·877	1381·548	2037·469
7	4059·393	1993·340	10726·425	2717·963	1993·340	10726·425
8	1289·277	1350·456	5528·196	7845·485	1350·456	5528·196
9	10265·073	4059·393	4173·728	9141·782	4059·393	4173·728
10	4623·044	1289·277	5994·061	16695·412	1289·277	5994·061
11	1007·953	10265·073	1499·393	11806·088	10265·073	1499·393
12	2206·464	4623·044	22333·430	4703·781	4263·044	22333·430
13	2518·880	1007·953	1399·600	10743·476	1007·953	1399·600
14	5077·877	2206·464	2803·714	10660·231	2206·464	2803·714
15	2717·963	2518·880	248·729	4543·812	2518·880	248·729
16	7845·485	5077·877	1381·548	2037·469	5077·877	1381·548
17	9141·782	2717·963	1993·340	10726·425	2717·963	1993·340
18	16695·412	7845·485	1350·456	5528·196	7845·485	1350·456
19	11806·088	9141·782	4059·393	4173·728	9141·782	4059·393
20	4703·781	16695·412	1289·277	5994·061	16695·412	1289·277
21	10743·476	11806·088	10265·073	1499·393	11806·088	10265·073
22	10660·231	4703·781	4623·044	22333·430	4703·781	4623·044
23	4543·812	10743·476	1007·953	1399·600	10743·476	1007·953
24	2037·469	10660·231	2206·464	2803·714	10660·231	2206·464
25	10726·425	4543·812	2518·880	248·729	4543·812	2518·880
26	5528·196	2037·469	5077·877	1381·548	2037·469	5077·877
27	4173·728	10726·425	2717·963	1993·340	10726·425	2717·963
28	5994·061	5528·196	7845·485	1350·456	5528·196	7845·485
29	1499·393	4173·728	9141·782	4059·393	4173·728	9141·782

Source : RIMP Survey data.

Table A 3. *Total rubber area under Strategy 3 (ha.)*

AGE	1978	1980	1990	2000	2010	2020
	YEAR					
0	16800·220	2373·955	10743·476	1007·953	1399·600	2037·469
1	1399·600	17·551	10660·231	2206·464	2803·714	10726·425
2	2803·714	16800·220	4543·812	2518·880	248·729	5528·196
3	248·729	1399·600	2037·469	5077·877	1381·548	4173·728
4	1381·548	2803·714	10726·425	2717·963	1993·340	5984·061
5	1993·340	248·729	5528·196	7845·485	1350·456	1499·393
6	1350·456	1381·548	4173·728	9141·782	4059·393	3141·704
7	4059·393	1993·340	5994·061	16695·412	1289·277	2373·955
8	1289·277	1350·456	1499·393	11806·088	10265·073	17·551
9	10265·073	4059·393	3141·704	4703·781	4623·044	16800·220
10	4623·044	1289·277	2373·955	10743·476	1007·953	1399·600
11	1007·953	10265·073	17·551	10660·231	2206·464	2803·714
12	2206·464	4623·044	16800·220	4543·812	2518·880	248·729
13	2518·880	1007·953	1399·600	2037·469	5077·877	1381·548
14	5077·877	2206·464	2803·714	10726·425	2717·963	1993·340
15	2717·963	2518·880	248·729	5528·196	7845·485	1350·456
16	7845·485	5077·877	1381·548	4173·728	9141·782	4059·393
17	9141·782	2717·963	1993·340	5994·061	16695·412	1289·277
18	16695·412	7845·485	1350·456	1499·393	11806·088	10265·073
19	11806·088	9141·782	4059·393	3141·704	4703·781	4623·044
20	4703·781	16695·412	1289·277	2373·955	10743·476	1007·953
21	10743·476	11806·088	10265·073	17·551	10660·231	2206·464
22	10660·231	4703·781	4623·044	16800·220	4543·812	2518·880
23	4543·812	10743·476	1007·953	1399·600	2037·469	5077·877
24	2037·469	10660·231	2206·464	2803·714	10726·425	2717·963
25	10726·425	4543·812	2518·880	248·729	5528·196	7845·485
26	5528·196	2037·469	5077·877	1381·548	4173·728	9141·782
27	4173·728	10726·425	2717·963	1993·340	5994·061	16695·412
28	5994·061	5528·196	7845·485	1350·456	1499·393	11806·088
29	1499·393	4173·728	9141·782	4059·393	3141·704	4703·781
30	3141·704	5994·061	16695·412	1289·277	2373·955	10743·476
31	2373·955	1499·393	11806·088	10263·073	17·551	10660·231
32	17·551	3141·704	4703·781	4623·044	16800·220	4543·812

Source : RIMP Survey data

Table A 4. *Total rubber area under Strategy 4 (ha.)*

YEAR

AGE	1978	1980	1990	2000	2010	2020
0	5141·282	5141·282	5141·282	5141·282	5141·282	5141·282
1	1399·600	5141·282	5141·282	5141·282	5141·282	5141·282
2	2803·714	5141·282	5141·282	5141·282	5141·282	5141·282
3	248·729	1399·600	5141·282	5141·282	5141·282	5141·282
4	1381·548	2803·714	5141·282	5141·282	5141·282	5141·282
5	1993·340	248·729	5141·282	5141·282	5141·282	5141·282
6	1350·456	1381·548	5141·282	5141·282	5141·282	5141·282
7	4059·393	1993·340	5141·282	5141·282	5141·282	5141·282
8	1289·277	1350·456	5141·282	5141·282	5141·282	5141·282
9	10265·074	4059·393	5141·282	5141·282	5141·282	5141·282
10	4623·044	1289·277	5141·282	5141·282	5141·282	5141·282
11	1007·953	10265·074	5141·282	5141·282	5141·282	5141·282
12	2206·464	4623·044	5141·282	5141·282	5141·282	5141·282
13	2518·880	1007·953	1399·600	5141·282	5141·282	5141·282
14	5077·877	2206·464	2803·714	5141·282	5141·282	5141·282
15	2717·963	2518·880	248·729	5141·282	5141·282	5141·282
16	7845·485	5077·877	1381·548	5141·282	5141·282	5141·282
17	9141·783	2717·963	1993·340	5141·282	5141·282	5141·282
18	16695·412	7845·485	1350·456	5141·282	5141·282	5141·282
19	11806·088	9141·783	4059·393	5141·282	5141·282	5141·282
20	4703·781	16695·412	1289·277	5141·282	5141·282	5141·282
21	10743·475	11806·088	10265·074	5141·282	5141·282	5141·282
22	10660·231	4703·781	4623·044	5141·282	5141·282	5141·282
23	4543·812	10743·475	1007·953	1399·600	5141·782	5141·282
24	2037·469	10660·231	2206·464	2803·714	5141·282	5141·282
25	10726·425	4543·812	2518·880	248·729	5141·282	5141·282
26	5578·196	2037·469	5077·877	1381·548	5141·282	5141·282
27	4173·728	10726·425	2717·963	1993·340	5141·282	5141·282
28	5994·061	5528·196	7845·485	1350·456	5141·282	5141·282
29	1499·393	4173·728	9141·783	4059·393	5141·282	5141·282
30	3141·704	5994·061	16695·412	1289·277	5141·282	5141·282
31	2373·955	1499·393	11806·088	10265·074	5141·282	5141·282
32	17·551	3141·704	4703·781	4623·044	5141·282	5141·282
33	1203·526	2773·955	10743·475	1007·953	1399·600	1713·761
34	1024·501	17·551	660·074	2206·464	314·161	0·000
35	0·000	1203·526	0·000	2518·880	0·000	0·000
36	1697·473	172·846	0·000	5077·877	0·000	0·000
37	2008·384	0·000	0·000	2717·963	0·000	0·000
38	0·000	0·000	0·000	7845·485	0·000	0·000
39	3194·359	0·000	0·000	2337·789	0·000	0·000
40	240·705	0·000	0·000	0·000	0·000	0·000
41	1762·163	0·000	0·000	0·000	0·000	0·000

Table A 5. *Total rubber area under Strategy 5 (ha.)*

	YEAR					
AGE	1978	1980	1990	2000	2010	2020
0	7910	3142	7208	4102	4809	6765
1	1391	4670	6728	6750	3193	4384
2	2803	7864	5293	6085	3523	4923
3	249	1391	6241	3839	2833	3803
4	1379	2798	6125	3197	3499	4183
5	1993	248	4827	7114	2604	4320
6	1350	1378	5220	5552	4706	3840
7	4041	1984	6515	5305	4940	4944
8	1289	1344	4705	7793	7664	3461
9	10264	4040	6040	6091	6809	6730
10	4619	1287	3100	7112	4048	4745
11	1008	10255	4635	6687	6669	3169
12	2206	4619	7805	5253	6039	3497
13	2519	1008	1318	6195	3810	2812
14	5077	2203	2782	6090	3179	3479
15	2717	2518	246	4800	7073	2859
16	7834	5069	1369	5184	5513	4673
17	9141	2714	1979	6497	5291	4927
18	16695	7834	1340	4064	7773	7645
19	11801	9138	4029	6022	6073	6789
20	4703	16688	1285	3093	7097	4039
21	10712	11767	10204	4611	6653	6666
22	10651	4686	4592	7760	5223	6005
23	4526	10663	998	1368	6136	3775
24	2017	10508	2164	2729	5975	3118
25	10626	4440	2447	240	4665	6875
26	4974	1798	4440	1199	4540	4825
27	4077	9340	2322	1693	5559	4527
28	5782	4688	6466	1106	5559	4527
29	1435	3766	7224	3185	4761	4802
30	2569	4529	10793	831	2000	4590
31	2090	1034	6718	5826	2633	3799
32	15	1752	2073	2032	3434	2311
33	1145	1540	4509	422	578	2595
34	991	13	4543	894	1128	2470
35	—	1084	1811	998	98	1903
36	1640	937	787	1945	525	1988
37	1988	—	4147	1030	751	2467
38	—	—	2122	2928	501	1519
39	3145	1598	1753	3363	1483	2216
40	238	1927	2555	6089	469	1128
41 & above	1753	3102	659	4285	3716	1679

Source : RIMP Survey data.

APPENDIX B

Table B 1. *Yield curve under different Strategies area below 40·5 ha.*

Year of tapping	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Hypothetical curve
0	420	560	560	450	450	800
2	672	700	700	630	650	1000
3	840	805	805	900	750	1200
4	980	910	910	1035	850	1350
5	1120	980	980	1053	870	1450
6	1120	1050	1050	1080	900	1550
7	1120	1120	1120	1134	980	1654
8	1120	1170	1170	1215	1020	1700
9	1232	1190	1190	1180	1040	1750
10	1232	1210	1230	1220	1150	1800
11	1232	1210	1230	1210	1150	1800
12	1232	1190	1200	1210	1140	1650
13	1232	1170	1180	1200	1060	1700
14	1232	1140	1160	1180	1040	1650
15	1064	1110	1120	1140	1020	1550
16	1064	1010	1010	1010	1010	1500
17	1064	960	950	940	950	1350
18	980	860	840	840	820	1250
19	960	770	750	750	730	1150
20	960	630	650	730	630	900
21		700	700	700	640	650
22		900	900	850	720	650
23		800	800	800	720	600
24		700	700	700	650	600
25			700	650	640	580
26			650	650	640	580
27			600	650	640	560
28				640	630	560
29				640	620	560
30				600	620	560
31				550	580	580
32				540	540	540
33				540	540	540
34					530	530
35					520	520
36					510	510

Table B 2. *Yield curve under different Strategies area above 40·5 ha.*

Year of tapping	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5	Hypothetical yield curve
1	420	640	640	640	640	1000
2	728	800	800	800	800	1200
3	924	920	920	920	920	1450
4	1092	1040	1040	1020	1020	1600
5	1176	1120	1120	1120	1100	1700
6	1232	1200	1200	1200	1180	1800
7	1288	1280	1280	1280	1240	1900
8	1344	1330	1300	1270	1280	1950
9	1300	1360	1340	1320	1310	2000
10	1400	1380	1360	1360	1340	2050
11	1400	1380	1380	1380	1340	2050
12	1400	1360	1340	1320	1320	2000
13	1400	1340	1320	1320	1300	1950
14	1400	1300	1300	1280	1260	1900
15	1400	1250	1250	1250	1250	1800
16	1400	1160	1160	1140	1120	1750
17	1400	1100	1100	1100	1000	1650
18	1300	1100	1100	1100	1000	1500
19	1200	1000	1000	1000	980	1400
20	1150	980	960	800	820	1200
21		40	820	800	780	1000
22		1000	980	980	840	1000
23		960	940	900	860	1020
24		940	920	800	720	950
25			1000	1000	860	940
26			1000	900	880	920
27			980	960	860	900
28				910	800	900
29				900	860	880
30				840	860	820
31				820	860	820
32				820	840	820
33				820	810	780
34					780	760
35					760	730
36					720	720

APPENDIX C

Total production of rubber under 5 Strategies — Sri Lanka

Year	Strategy 1	Strategy 2	Strategy 3	Strategy 4	Strategy 5
1978	199874·490	213895·800	218076·780	225541·460	223698·730
1979	187171·770	208607·950	213836·750	218267·680	215911·590
1980	182234·480	200477·180	208450·650	211147·700	209739·890
1981	172511·600	190913·910	199676·050	200966·910	198957·350
1982	157740·340	180247·010	191954·390	190586·670	189156·990
1983	143475·160	166392·740	181737·790	180992·600	178502·390
1984	168928·310	178352·700	187001·690	175057·140	174968·640
1985	168636·800	172002·100	177393·600	168011·070	168079·360
1986	160044·570	166321·880	167099·240	162685·940	160622·000
1987	159957·970	160912·200	165353·530	160431·530	158171·460
1988	165846·700	162058·160	161014·300	159559·080	155995·470
1989	178117·540	163526·360	156869·640	159615·610	156179·030
1990	185272·510	155599·710	152416·910	160665·390	155919·460
1991	198905·080	154659·270	153349·540	161861·990	156172·520
1992	218282·180	160669·260	155082·450	163926·140	157342·810
1993	234143·020	171556·400	146800·160	166048·260	160609·760
1994	243618·640	174761·880	144309·430	166879·680	161777·150
1995	241609·810	185981·490	148278·890	168438·870	163991·020
1996	248766·260	203637·220	158766·380	171649·440	170766·790
1997	251056·980	217591·440	163673·630	174528·970	176395·560
1998	252563·070	227376·260	176142·460	177494·060	182237·380
1999	251990·320	228117·810	194488·360	180329·290	185628·580
2000	251730·190	234502·700	208126·570	183155·860	190534·830
2001	255980·980	235996·790	218355·320	185401·310	194289·540
2002	250892·970	237897·570	218832·220	187270·330	194068·130
2003	243631·160	233621·230	224088·410	188459·020	194501·660
2004	199874·490	231968·110	224928·250	188888·330	195821·030
2005	187171·770	239085·650	229130·580	189430·990	199896·770
2006	182234·480	235811·890	228721·770	189650·500	200867·900
2007	172511·600	234841·860	230857·440	189987·040	204017·210
2008	157740·340	213895·800	237747·010	190239·210	207257·800
2009	143475·160	208607·950	234656·930	190500·660	208363·040
2010	168928·310	200477·180	234049·800	190585·910	208516·650
2011	168636·800	190913·910	218076·780	190589·050	204896·070
2012	160044·570	180247·010	213836·750	190589·050	202980·400
2013	159957·970	166392·740	208450·650	190589·050	199536·300
2014	165846·700	178352·700	199676·050	190589·050	197084·200
2015	178117·540	172002·100	191954·390	190589·050	193202·660
2016	185272·510	166321·880	181737·790	190589·050	191034·060
2017	198905·080	160912·200	187001·690	190589·050	190985·800
2018	218282·180	162058·160	177393·600	190589·050	187829·640
2019	234143·020	163526·360	167099·240	190589·050	186837·850
2020	243618·640	155599·710	165353·530	190589·050	183138·470

Source : RIMP Survey data.

THE IMPACT OF GOVERNMENT POLICIES ON INVESTMENT IN THE RUBBER INDUSTRY OF SRI LANKA

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Throughout the 1970's the Sri Lankan rubber industry stagnated in terms of output, cultivated area and share of gross domestic product (GDP) see Table 1. Such a decline, in itself, is no cause for concern ; indeed, it is to be expected that as economic development proceeds, the role and significance of labour intensive primary product industries would diminish after a certain stage. However, it is difficult to attribute the decline of the Sri Lankan rubber industry to the process of economic growth. A review of the past period suggests that the content and implementation of a series of government policies contributed far more than general economic development to the decline of the industry. And this occurred during a period in which the industry could potentially have made an enhanced contribution to the national economy, facilitating a higher rate of growth.

Table 1. *Some basic statistics of the Sri Lankan rubber industry : 1970 — 1983*

Year	Area (hectares)	Production (millions of kilogrammes)	Share of gross domestic product (%)	Share of exports (%)	Average yield (kilogrammes per hectare)
1970	230,324	159	1·7	21·6	792
1971	229,957	142	1·3	15·0	736
1972	229,579	140	1·2	13·3	737
1973	228,744	155	1·7	22·6	778
1974	228,100	132	1·3	21·1	710
1975	227,730	149	1·5	16·5	774
1976	227,074	152	1·5	18·4	790
1977	226,660	146	1·3	14·0	773
1978	226,420	156	1·3	15·3	845
1979	226,419	153	1·2	16·3	820
1980	229,335	133	1·0	14·7	718
1981	205,605	124	0·9	13·7	705
1982	205,690	125	0·8	10·8	729
1983	205,649	135	0·9	11·0	823

Source : *Annual Review of the Economy*, Central Bank of Ceylon, Colombo.

After the 1950 — 51 Korean War related price boom, rubber prices followed a secular decline for some two decades ; a clear falling trend was most apparent during 1960 — 1972. Other things remaining constant, this would have automatically led to lower profitability and, where attractive alternatives were present, to lower levels of investment. However, other things were not, or at least were not necessarily, constant. The national rubber industry had developed the potential for major technological changes which could drastically reduce the cost of production. The most important of available new technologies were embodied in new cultivars, which had a yield potential many times that of the trees planted a few decades ago. Replacement of older trees with new high yielding cultivars, together with associated new technologies, could have raised per hectare yields substantially and reduced the cost of production which could have offset the downward pressure on profitability due to falling prices. This was the path broadly traversed by the Malaysian rubber industry (Barlow, 1978) ; as a result, when rubber prices were more favourable in the 1970's, it was in a position to register high levels of output and profits. Despite substantial replantings the Sri Lankan industry proved unable to take advantage of the favourable period in the 1970's and yields and exports stagnated.

Sri Lankan government policies, or rather policy statements, have always stressed the importance of the plantation crop sector and the need to enhance its output and productivity. Indeed, a number of direct policy measures were aimed at achieving these objectives. These included replanting grants, provision of research and extension services and subsidised fertiliser inputs. There is no doubt that these had beneficial effects. Little new planting was undertaken after the early 1950's, partly because most suitable lands were already under rubber cultivation ; new investment refers most importantly to replanting. The replanting grants, availability of high yielding cultivars and an effective extension service contributed to the substantial replanting with new cultivars which occurred during the 1950's (and to a lesser extent in the 1960's). These replantings were the major factor behind rising yield levels from the mid 1950's, a trend which continued till the end of the 1960's. By 1970, average yields had nearly doubled over those in 1953, an impressive achievement in a long lived crop industry. These yield gains, however, masked parallel processes which were to result in the stagnation of yields and the decline of the industry during the 1970's.

In Tables 2 and 3 we present some figures on rubber replantings, most of which involved high yielding cultivars (due to limited access to Sri Lankan data, we are unable to present replanting performances by sub-groups after 1973). The rapid decline of the large estate replantings after the early period of the replanting subsidy scheme preceded the very low prices of the 1960's. However, till the late 1960's, the other sub-groups showed a respectable replanting performance. A detailed discussion of the replanting performance up to 1970, in the context of policies directly affecting the rubber sector, has been presented by Wijepala and Senanayaka (1970). An econometric analysis of replanting activities (Herath, 1975) found that profitability considerations were dominant in explaining the behaviour of the three producer groups. Further econometric analysis which puts particular emphasis on the major role of replantings in supply response of Sri Lankan rubber is currently under way (Nerlove, M : personal communication), and preliminary results indicate that the real level of the replanting grant is of major importance.

Table 2. *Area replanted by size group : 1953 — 1973*

Year	Replanted area (acres)		
	Estates over 100 acres	Estates 10 - 100 acres	Smallholdings under 10 acres
1953	4,346	989	465
1954	9,408	5,126	3,923
1955	9,164	6,135	5,608
1956	10,803	7,012	6,770
1957	9,939	7,481	6,809
1958	8,270	5,821	6,547
1959	6,185	4,566	7,781
1960	6,164	4,538	7,191
1961	7,617	4,135	6,933
1962	7,741	3,490	6,993
1963	7,071	2,694	6,147
1964	4,797	3,851	4,904
1965	4,498	3,171	4,832
1966	4,608	2,131	4,842
1967	4,664	2,120	3,302
1968	6,100	2,352	4,282
1969	6,225	1,747	4,112
1970	4,998	1,708	3,533
1971	4,130	1,365	2,981
1972	5,283	1,109	2,350
1973	4,053	925	2,298
Cumulative Total	135,794	72,468	102,604

Source : *Administration Report of the Rubber Controller for 1973.*

Table 3. *Total annual replanted areas after 1973*

Year	Area (acres)
1974	7,076
1975	7,980
1976	6,299
1977	6,464
1978	7,968
1979	10,294
1980	13,422
1981	15,912
1982	14,489
1983	12,643

Source : *Report of the Central Bank of Ceylon, 1983.*

The replanting performance declined during the 1960's and was quite low until the late 1980's, when substantially higher replanting grants and favourable price expectation lifted the rate up ; this was also due to the implementations of the rubber rehabilitation programme under World Bank assistance. However, due to the below target performance of replanting in the past (and as areas replanted in the early 1950's are again coming due for replanting) higher levels need to be achieved if productivity levels are to be improved.

Most discussions of the policies of the rubber industry in Sri Lanka have paid attention to the direct effects of government policies which affected profitability. These include the political environment created by the nationalisation, land reform issues and the export tax. However, to appreciate the full extent of the impact of government policies these should be assessed in the context of overall government policy affecting all sectors of the economy. Within the substantial data and time constraints, in this paper we hope to make an initial contribution towards such a study.

The nationalisation issue

The coming into power of a government pledged to nationalise foreign owned plantations drastically changed the investment climate for foreigners from 1956 ; they were not to know that two decades would pass before the government would move in to acquire foreign plantations with appropriate compensation. The policy of proclaiming the intention to nationalise but postponing its actual implementation ensured, as Kaldor (1958) pointed out, that the foreign estates industry had the worst of both worlds. Investment in technical change, particularly in the crucial replantings, would yield benefits only in the long run. Given the uncertainty regarding the date of nationalisation and the distinct possibility of lower than market value compensation levels, privately optimal policy for foreign plantations was clearly to reduce long term investments and to increase the rate if exploitation of current fixed capital stock. The " running down " of trees and equipment was inevitable. Some decline in replantings in the large estate sector towards the end of the 1950's was to be expected anyway, since a backlog of replantings were undertaken in the early years of the replanting subsidy scheme initiated in 1953 ; however, there is no doubt that the continuing low levels of replanting reflected the desire to reduce investment in the Sri Lankan rubber industry by foreign interests. Where possible foreign companies reduced their ownership of rubber plantations ; by 1974 they owned less than one third of the estates (though admittedly these included some of the most productive rubber area).

The trade policies

The nationalisation threat directly affected only the foreign owned sub-sector. The changes in the trade policies, particularly from the late 1950's, affected the entire industry. However, the main consequence of these changes was to progressively reduce, both absolutely and relatively, the incentives for investment in rubber. The trade regime embodied an anti-agricultural and[1] anti-export bias which particularly affected rubber, in an environment of declining prices.

1. Jayasuriya (1981) has argued that government policies became relatively more favourable towards the domestic food crop sector during the late 1950's and thereafter ; however, this only highlights the discrimination against export agriculture.

The deterioration of rubber and tea prices and rising domestic inflation during the late 1950's were reflected in growing balance of payments difficulties. These, together with the emphasis on import substituting industrialisation as the strategy for economic development led to increasing trade restrictions on imports. By 1962 such restrictions, operating both through high tariffs and more importantly through quantitive restrictions had become quite pervasive. This is not the place to go into an exhaustive discussion of the experience of the Sri Lankan experience with import substituting industrialisation behind high levels of effective protection. It should be noted, however, that while the rate of growth of the industrial sector was fairly rapid and higher than that of gross national product (GNP), the rate of value added has been relatively low and the import content of many new industries has been quite high. Industrialisation was quite "thin", confined generally to light consumer goods and catered mostly to the small domestic market. By the end of the 1960's much of the scope for import substitution in major sectors was already exhausted.

The shift towards this particular kind of industrialisation *necessarily* involved discrimination against agriculture, particularly against export oriented agriculture. Changes in domestic producer incentives are influenced by relative prices. Tariff and non-tariff barriers to imports raise their domestic prices, increase profitability of investment in their production, and distort the relative prices in their favour *vis a vis* other commodities. In the Sri Lankan context, import substitution was most significant in the industrial sector and the export agricultural sector was the most adversely affected. Fernando (1979) has reported on levels of protection (and their consequences) in some industries. The effective rates of protection[2] were often over 100 percent, and rates as high as 400 per cent were not uncommon. Tariffs were low on imported raw materials and intermediate goods ; these contributed to the import intensive character of the industrialisation by discouraging backward linkages. We do not have precise estimates of the import content of rubber production in Sri Lanka ; the artificial cheapening of imports may have lowered the costs of these, but it is unlikely that this would have had any appreciable favourable impact as the import content was low. In sharp contrast to these industrial protectionist measures, export taxes on the traditional plantation crops were quite high (except when prices were extremely low). These export taxes were the main source of government revenue. Table 4 presents data on export taxes in rubber during the 1970's. From very low levels during the early 1970's when prices were highly depressed, they have risen to over fifty percent in recent years.

Impact of export taxes on profitability

Tables 5 and 6 present some indications of the impact of export taxes on profitability. They are presented to illustrate the general trends, and are not meant to be accurate estimates of actual rates of profits. The cost of production figures are averages and their basis is not known to us. Despite these limitations, they do provide interesting information for the period 1970 — 1981.

2. These refer to the EPR estimates given in Fernando's paper.

Table 4. *Export taxes (including levies, cesses etc. on rubber)*

Year	Total tax Rs.-million	Value of exports Rs.-million	Tax as percentage of export value
1970	70	439·7	16
1971	14	306·8	5
1972	12	265·1	5
1973	141·5	591·5	24
1974	284·3	738·5	38
1975	139·6	653·7	21
1976	197·4	889·6	22
1977	260·6	930·6	28
1978	1001·0	2020·0	50
1979	1239·0	2491·4	50
1980	1368·5	2590·4	54
1981	1432·5	2889·0	50

Sources : (i) *Annual Review of the Economy*, Central Bank of Ceylon, various issues
(ii) *Government Financial Statistics* (IMF) — various issues.

Table 5. *Profitability of f.o.b. prices*

Year	Average f.o.b. price (Rs./Kg)	Average cost of production (COP) (Rs./Kg)	Rate of 'profit'*	Rate of profit in terms of 1970 figure
1970	2·73	1·52	80	100
1971	2·38	1·67	30	38
1972	2·05	1·65	24	30
1973	3·68	1·87	97	121
1974	5·75	2·46	134	168
1975	4·05	2·75	47	59
1976	6·50	3·28	98	123
1977	6·85	3·74	83	104
1978	14·90	4·85	207	259
1979	19·44	6·86	183	229
1980	21·42	8·20	161	202
1981	21·80	8·92	144	180

$$\text{*Rate of 'profit'} = \frac{\text{f.o.b. price — cost of production}}{\text{cost of production}} \times 100$$

Source : *Annual Review of the Economy*, Central Bank of Ceylon, various issues.

Table 6. *Profitability at domestic producer prices*

Year	Average* domestic price (Rs./Kg)	Average cost of production (Rs./Kg)	Rate of 'profit'†	Rate of profit in terms of 1970 figure
1970	2·29	1·52	51	100
1971	2·26	1·67	35	69
1972	1·95	1·65	18	35
1973	2·80	1·87	50	98
1974	3·57	2·46	45	88
1975	3·20	2·75	16	31
1976	5·07	3·28	54	106
1977	4·93	3·74	31	61
1978	7·45	4·85	53	104
1979	9·72	6·86	41	80
1980	9·85	8·20	20	40
1981	10·90	8·92	22	43

* Average domestic price was computed as :

$$\frac{\text{Total export revenue} - \text{Export taxes, levies etc.}}{\text{Total volume of exports}}$$

$$\dagger\text{Rate of 'profit'} = \frac{\text{Average domestic price} - \text{cost of production}}{\text{Cost of production}} \times 100$$

Source : *Annual Review of the Economy*, Central Bank of Ceylon, various issues.*

Clearly, at the aggregate level, the profitability of the rubber industry is substantial from a national view point[3] ; the difference between domestic cost of production (COP) and the border (f.o.b.) price has been very significant throughout the 1970's. Even before the exchange rate reforms and the associated devaluation in 1977, the rate of 'profit' was never below 30 percent and ranged as high as 134 percent in later years ; it has been always higher than 100 percent. However, producer profitability shows a different picture due to the export taxes which sharply reduce domestic prices below the border price. The level of the total tax (including levies and cesses) as a proportion of export revenues reached 50 percent in 1978 and was maintained in subsequent years. The resulting impact on producer profits has been quite severe (Table 6)[4]. Further, rubber estates were subject to the usual company taxes, while many new industrial and non-traditional enterprises were granted generous tax holidays ; this tax would have affected relative profitability substantially.

3. More accurate estimates of the social profitability could be obtained by computing domestic resource costs ; however, data constraints did not permit this.

4. As a small fraction of the levy is transferred back to the industry in the form of replanting grants, research, expenditure etc, this figure over estimates the impact of the tax on producer profits. On the other hand, marketing and storage costs may not have been included in the COP.

An examination of the profitability rates show that when the border prices are considered the industry has become substantially more profitable during the end of the decade compared with the early years ; this is due to better prices and very importantly to the more favourable exchange rate since 1977. However, the producer profitability shows a different situation. Once export taxes are taken into account, the profitability in later years is markedly lower. Even in 1978, the exchange rate adjustment only arrested the declining profitability in previous years, restoring it to the 1970 level. In subsequent years the decline has been sharp ; by 1981 it was only 43 percent of the 1970 level. Clearly, the impact of all the policy changes in 1970's did not halt the declining trend in producer profits. This point will be taken up again later.

The exchange rate policies

The exchange rate policies further aggravated the bias. Adverse movements in the terms of trade (which deteriorated by an average annual compound rate of 5·5 percent during the 1960's) resulted in a continuing trade imbalance. This occurred despite import restrictions and even a slight upward movement in import volumes. Though there was a widespread perception that the currency was overvalued, no significant change in the (fixed) exchange rate was undertaken until November 1967 when the Rupee was devalued by 20 percent in the aftermath of the devaluation of the British pound. In May, 1968 a dual exchange rate system, the Foreign Exchange Entitlement Certificates (FEEC'S) system, was introduced and was maintained until 1977.

According to the FEEC'S system, certain foreign exchange receipts and payments were subject to a premium rate which rose from 44 percent to 55 percent in 1969 and to 65 percent in 1972. While some investment and raw material imports were brought under the scheme, many export goods, particularly non-traditional commodities were permitted to obtain the higher rate (Kappagoda & Paine, 1981). However, tea, rubber and coconut were excluded from this category. The exclusion of the plantation crops from the FEEC'S scheme, which gradually broadened to include a large proportion of the foreign trade sector, was a heavy implicit tax on these crop sectors ; it exacerbated the effects of the already substantial export tax and the positive protection granted to industry.

Employment and efficiency consequences

Thus, both the trade regime and the exchange rate policies operated to reduce producer incentives in the export crop sector ; these adverse effects were not balanced by the research, extension and fertiliser subsidies which returned a small proportion of the export taxes back to the industry.

These policies had important consequences. They encouraged the development of a large group of inefficient industries. In the state sector, these took the form of a larger number of ' white elephants ' which needed continual injections of new funds for survival despite the high levels of protection and other implicit subsidies. Many of the new private sector industries, too, never managed to outgrow their infancy, catering to a limited home market with little prospects of surviving without protection. However, these constituted more profitable investment alternatives, for private investors pulled investment capital away from plantation crops. Being generally more capital intensive, the protection granted to these industries would have raised returns to capital and shifted relative prices to the disadvantage of labour.[5] Further, their capital intensive nature would have inevitably led to employment levels below what could have been achieved otherwise. The overvalued exchange rate which reduced the price of imported capital goods strengthened this anti-employment effect.

In addition to the protection granted to import substituting industries, there was an active policy of providing added incentives to the so called non-traditional agricultural crops. Planting subsidies, subsidised credit and FEEC'S incentives were made available to these crops. Again, the effect on relative profitability was similar, though there was little growth in the production and export of these crops in the 1960's, though some crops registered substantial expansion during the 1970's. The industrial protection sometimes acted to reduce exports of some of these minor crops (such as cocoa) by diverting them into home market oriented production. Also, despite the incentives of the FEEC'S, the relatively high export taxes discouraged official exports (Wijewardana, 1973). Further incentives had to be granted to obtain significant growth, and later these export taxes were drastically reduced for most such crops.

The marked decline in replanting in the medium estates sector during the 1960's (Table 2) was probably a clear reflection of the movement of domestic capital away from the rubber industry into these new, more privately profitable investment outlets. The comparatively better replanting rate achieved by the smallholders can be understood if we take into account the fact that rubber replanting was a substantial *labour* investment for them rather than a capital investment ; even the larger smallholders probably found investment in land to be sufficiently attractive, given the land market imperfections and the often lumpy investments needed to enter into the new industries. Cost pressures, too, were perhaps lowest in the smallholding sector which had greater flexibility in terms of labour use.

The rationale for discriminatory policies

The discriminatory policies towards export agriculture, or rather the favourable policies towards industrial protection and non-traditional crops, were justified on a number of grounds. The most commonly advanced reasons included the desirability of industrial development as a necessary pre-condition for sustained economic growth and the need for diversification of the economy to reduce dependence on a small number of primary goods whose prices fluctuated violently around a declining trend. These arguments have been advanced elsewhere and in different contexts ; both economic theory and actual experience suggest that the proponents of these arguments often failed to realise the nature of the premises on which they were based or the consequences which almost always followed. Of course, groups who gained economic rents from protectionist policies exercised much political pressure to enforce and maintain these.

5. This follows from the Stoper-Samuelson theorem ; for a discussion, see Chipman (1966).

Here, we shall take up some of the issues raised ; for a more comprehensive review of the theoretical issues the reader is referred to Corden (1974). The empirical experience of import substituting industrialisation has been analysed extensively (see, for example, Krueger, 1978).

The need for special treatment, for tariff protection, tax holidays and similar favourable policies for industries has been often based on the so-called "infant industry argument". While presented in many forms, it usually involves the proposition that new industries cannot be expected to originate and develop if they are immediately subject to international competition ; they require time for "learning" how to produce and market their products efficiently. Further, capital market imperfections in many less developed countries cause under investment in socially desirable industrial development ; lack of relevant information denies potential entrepreneurs the knowledge needed for assessing and choosing profitable new industrial investments. None of these considerations, however, necessarily justifies specially favourable policies for industry at the expense of agriculture. As Corden (1974) points out : "In less developed countries private agriculture usually finds capital harder to obtain and more costly than industry, and surely a lack of information or foresight is a greater weakness of farmers than of urban industrialists. Furthermore, the scope for learning in agriculture is often immense". The latter point is particularly strong where new technologies are becoming available in agriculture. In any case, the first best policies to overcome capital and information market imperfections would be the removal of barriers to access needed capital and the improvement of information supply. The industrial protectionist policies impose both static and dynamic efficiency losses on the economy. In the Sri Lankan case, as elsewhere, the diversion of scarce capital and skilled manpower to the establishment and perpetuation of inefficient industries in both private and state sectors has certainly imposed heavy costs by stifling economic activity and restraining the development of those sectors where the country had a real comparative advantage.

There are few strong arguments for government intervention to facilitate diversification in agriculture. Lack of information about future price movements may hold back farmers from shifting to more profitable crops. This argument appears quite weak in the case of annual crops, as adjustments can be made relatively rapidly once the price changes takes place. However, there may be some grounds for it to apply in the case of perennial crops as factors other than information alone (such as time preference rates which differ from the social discount rate) may prevent farmers from responding in the desired manner. The second argument is that greater stability of incomes is desirable and this would necessitate diversification.

Here it must be stressed that diversification for income stability is not costless ; its costs must be weighed against potential benefits as income stability may be brought about at the expense of higher average incomes if the changes require a shift away from the most profitable crops. On the basis of the Sri Lankan experience, we would argue that there is no compelling evidence that average incomes may have improved during the past decade as a result of crop diversification brought about by artificially distorting producer incentives.

It is a fact that the export composition exhibited greater diversity at the end of the 1970's. However, to a considerable extent the reduction of the share of the traditional plantation crops in export revenues was brought about by the stagnant or even declining output of tea and rubber and the greatly reduced coconut exports. The sectors which grew more were the highly import intensive petroleum refinery operations and the made up garment industry and these contributed the bulk of increased industrial exports. In Table 7, we present the behaviour of selected minor export crops prices relative to rubber price ; note that the 1970 rubber price was low. Clearly, the relative price trends show no uniform pattern. While cardamom and cinnamon relative prices moved up in general, cocoa, pepper and cloves prices moved down. In terms of potential technological change, rubber was best placed at the beginning of the period ; hence it could be argued that high yields resulting from replanting could have compensated even where relative price movements were somewhat unfavourable. In any case, without a much more disaggregated and careful study there is no room for asserting that the distortion of incentives to favour minor export crops has helped increase national income during the 1970's. It is quite likely that the gains from greater diversification were substantially offset by efficiency losses arising from price distortions.[6]

Devaluation and profitability

The change in policies in 1977 was expected to substantially improve the prospects for the export crops. The 1977 devaluation (and exchange rate reform) immediately raised producer profits, despite the progressive tax structure which siphoned off half of the export proceeds as government revenue (Table 4). With the new exchange rate policy which signifies an end to an overvalued currency, it was hoped that a new, much more favourable period for exports, including rubber, had dawned. This was expected to improve long term profitability expectations and to result in higher levels of private investment in rubber. On closer examination, however, this appears not to be the case and raises the issue of whether devaluations stimulate growth in perennial crop industries. The major effect of a devaluation on the export sector is the change of domestic relative prices in favour of (internationally) traded goods *vis a vis* non-traded goods. Unless the country has market power in international trade, which is not the case with Sri Lankan rubber, there will be no effect on international prices. Recent studies of the experiences of devaluation have shown that much of the effect on relative prices of traded and non-traded goods is eroded quite rapidly (usually within 2 to 3 years) as the non-traded goods prices rise (for a discussion of some of these issues, see Branson, 1983); this then removes the original improvement in profitability. This is confirmed in the case of Sri Lankan rubber after the 1977 devaluation.

From Tables 5 and 6 we can see that within a comparatively short period of time the improved profitability resulting from the 1977 devaluation was lost. Without the export tax effect, the " profit " rate even in 1981 was significantly higher than in 1977. However, once the tax effects are considered, producer profitability was significantly lower in 1980 compared with 1977. This decline was not due to a decline in rubber prices,

6. This discussion does not imply that rubber should not be replaced by other crops when the agro-climatic conditions are clearly unsuitable for rubber. However, the overall incentive structure is baised against rubber, the private investors' choices will lead to replacement of rubber by other crops even where rubber may be more socially profitable.

as average f.o.b. as well as domestic prices rose during this period. Indeed, if there was no price rise the effects of the devaluation on profitability would have been negated even sooner. In Table 8, we show how rapidly profitability would have declined, if 1978 prices continued ; the producer profitability levels would have been completely eliminated by 1980.

Table 7. *Prices of selected minor export crops relative to rubber prices*

Year	Cocoa	Cardamoms	Pepper	Cloves	Cinnamon*
1970	100	100	100	100	100
1971	103	109	27	128	101
1972	110	154	42	144	93
1973	121	165	101	117	138
1974	96	262	98	127	150
1975	90	211	56	70	92
1976	96	172	49	89	132
1977	41	101	56	73	131
1978	54	110	88	114	129
1979	65	126	128	85	103
1980	106	159	126	70	191
1981	113	177	148	61	118

* All relative prices have been scaled such that

$$\frac{\text{1970 price of minor export crop}}{\text{1970 price of rubber}} = 100$$

@ (a) 1970 — 1972 — average price of all cinnamon products
(b) 1972 — 1981 — price of cinnamon quills

Source : (a) 1970 — 1972 — and 1980 — 1981 *Annual Review of Economy*, Central Bank of Ceylon

(b) 1973 — 1979 — *Economic and Social Statistics of Sri Lanka*, Central Bank of Ceylon.

Table 8. *Changes in profitability after 1977 devaluation at 1978 price*

Year	Rate of 'profit' at f.o.b. price	Rate of 'profit' at domestic price
1978	207	53
1979	147	9
1980	103	— ve
1981	84	— ve

* Data not adjusted for variations in exchange rate.

Clearly, rising costs of production due to domestic inflation were eroding profitability at a pace that restricted the positive effects of the devaluation to a very brief period. Thus if industry profit levels are to be maintained, a substantial revision of the tax structure appears to be of crucial importance. Such a revision should link tax rates to the price as well as to domestic cost increases. In a general sense, devaluations appear to do little to stimulate long run growth in the tree crop sector (or in any industry with a long gestation period). In rubber, tapping begins after 5 — 6 years and economic yields, even later. Such investments will not be made in response to short lived profitability improvements ; producers' response will be to maximise short run gains by intensive tapping (unless they expect a continuous series of devaluations).

Conclusions

From the available data and information, we would conclude that unless quite drastic measures are taken to increase and maintain profitability in the industry, the future outlook may be bleak. We understand that a substantial rise in replanting grants is being implemented. As replanting has responded quite positively to increased real levels of replanting grants in the past, this may hold hope for increasing the replanting rate, which has already shown some improvement at the end of the 1970's. Increased expenditure on replanting grants, financed from export taxes, will return a greater proportion of tax revenues to the industry. It will also raise expected profits for those contemplating replantings now ; however, it is unlikely that higher replanting grants alone can maintain producer profits in the industry. Both the export tax structure and the exchange rate policy would need to be revised and the progressive tax structure should be adjusted to take into account not only the world price movements but also the changes in domestic cost structure.

Future performance of the rubber industry will be affected by the distinction between the state owned large estate sector and the privately owned smallholding sector, whose cost structures are likely to be substantially different. If the state owned estates are not expected to act as profit making enterprises, then plan targets can be set and implemented without reference to export taxes etc, provided government funds are channelled to meet the needed expenditures. Such injections of funds will be essential if trends observed in the study period continue. There are major problems that may arise in implementing such a policy, however. It could easily breed inefficiency, corruption and mismanagement and more white elephants may be created in the state sector.

On the other hand, if they are to operate as profit making enterprises, the same influences which determine profitability in the private sector will operate. The fortunes of the entire industry will then depend on market forces which are heavily distorted by government policies. Due to the aggregated nature of the data available to us, we were unable to address the issue of variations in efficiency across and within subsectors. In formulating appropriate policies for the future, an analysis of the efficiency of the different subsectors should complement the other studies on tax, exchange rate and diversification policies impacting on the rubber sector.

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SESSION 12. PLANTERS' VIEWS

COMPARATIVE VIEW OF MANAGEMENT IN THE PLANTATION INDUSTRY IN SRI LANKA AND MALAYSIA

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Effective and efficient management is the key to maximising productivity ; even Socialist Nations have recognised this fact and are known to be introducing relevant Management Training Programmes.

This paper will endeavour to deal with Contemporary Management in the Plantation Industry with particular reference to my experience gained in Sri Lanka and in Malaysia.

During the last 30 years or so, there has been a very fundamental change in the Plantation Industry of practically all Countries having Plantation based economies.

This fundamental change that has taken place has been the transfer of vast assets consisting of Plantations from our ex-colonial masters back to Government Controlled Agencies of the Countries in which the land is actually situated. This change in ownership of the land and in other cases, the redomiciling of Companies owing the land has inturn inevitably resulted in structural changes in Plantation Management in Countries like Malaysia, Indonesia and Sri Lanka.

The method and style of change in ownership has varied from Country to Country. In some Countries like Indonesia, the changes have been dramatic to the extreme. In other Countries like Malaysia and Liberia, they have been more gradual but whether the change in ownership has been dramatic or gradual these changes have inevitably resulted in varying degrees, in the style and method of Plantation Management.

Method of change in land ownership

In Sri Lanka, both foreign owned and Sri Lankan owned Plantations were nationalised in 1974 and 1975 in 2 stages. Stage 1 being Sri Lankan owned Companies and private owned lands with certain limitations and Stage 2 being foreign owned Companies.

Indonesia also had the same experience as Sri Lanka where the Plantations were nationalised immediately after their Independence. Recently, foreign investors are being encouraged to return and experienced Planters, even after retirement, are being recruited to manage and train their personnel, to make the Agricultural Sector more effective and productive.

In Malaysia, the changes in ownership of Plantations was part of the New Economic Policy which provided for a gradual reduction in the foreign equity over a period of 20 years, commencing 1970. These changes provided for a reduction in foreign ownership of Plantation assets from 100% to a maximum of 30%. The acquisition of equity in foreign based Plantation Companies, resulted in the redomiciling of those foreign owned

Companies by purchasing shares in the open market in Malaysia and abroad. There has been no effect on the Malaysian owned Plantation Companies.

Change in management

Although there were changes in ownership of Companies in Malaysia, the Management Personnel were retained intact and continued with the policies and systems adopted by the respective Companies. The Government as far back as 1967, discussed with the Foreign Companies and due notice and guidelines were given to reduce the expatriate executive staff by the process of natural wastage over a period of 18 years. Thereafter, only key personnel would be treated as an exception.

However, in Sri Lanka the established Companies managing plantations became totally ineffective by Plantations being vested in the state and upto October 1980, the Management of Estates and its Managing Agents have been put to severe strain by frequent convulsive changes. These changes indicate that policies affected by the change in ownership haa not been properly planned prior to implementation.

Contemporary management

Morale — Key factor to effective management

For efficient and effective management, the morale of the Management Team is a key factor. The retention of the same Management and the continuity of the systems practised prior to change in the ownership greatly aided in maintaining the morale of Malaysian Planters and indeed the entire workforce. On the other hand, the frequent changes in the Management structure have caused a sense of insecurity as a consequence of which morale of the Sri Lankan Planter has declined. This will inevitably affect productivity of plantations, very much managed by the Planter — " The Man On the Ground," responsible for safeguarding and even enhancing the largest source of Foreign Exchange Earning for Sri Lanka.

Some of the key factors which should not be overlooked in maintaining or even raising the morale of the Planter are :—

(I) **Authority**

The Staff and the Workforce on the Estates must be aware that the decisions taken within policies and practices laid down and given out are those of the Planter. He must be seen to be the authority. The Planter's effective control over his Staff and Workforce is essential as the industry is labour intensive. Approximately 75% of the work is still done manually. Tc this end, the Planter should have the ultimate authority in respect of recruitment, disciplinary action, including dismissal of non-executives at least.

(II) **Political Influence**

Political influence should never be allowed to creep in to Plantation Management. Staff and Workforce should be aware of this. Planters themselves must be confident that they are only responsible to their senior management and Board of Directors. A sense of security of tenure would necessarily motivate Planters to treat their Estates as their 'Home'. Any feeling of being a 'Modern Day Nomad' must equally necessarily destroy Planters' morale and productivity is bound to suffer as a result.

(III) Bureaucratic control

Chain of command should be clearly defined and unnecessary red-tape should be eradicated to ensure effective management. Planters should be given authority to decide within given bounds.

It is important for Directors and Senior Management not to give the impression that they are 'Hard to Get' for discussion but to make themselves available to conscientious Planters enthusiastic with proposals for better achieving their targets. Building up of confidence between Planters and Directors would enhance morale of Planters. As we all are aware, "Management through discussion" has been proved to be successful over the years in meeting the set objectives and targets.

(IV) Discipline

As stated earlier, Staff and Workforce must be aware that the Manager is the final authority on the Estate, and that all decisions pertaining to disciplinary matters are within his sole purview. This must be included amongst policies laid down. This is an absolute necessity in any labour intensive Industry.

Procedures regarding the handling of disputes must continue on established principles and practices and should, if possible, be made uniform throughout the Industry.

(V) Recognition

Recognition should be shown by way of adequate remuneration and fringe benefits, in keeping with not only the round-the clock responsibilities a Planter shoulders, but the way of life he is required to lead to maintain his position and authority. His position cannot be generalised with those of most other sectors of the economy. A Planter mainly lives in isolation and away from the comforts of urban living, in many instances necessitating living away from his family so as to provide urban education for his children.

A well-motivated Planter would be one who is confident that besides his overall performance, including his initiative and drive, will be appreciated and recognised when it comes to transfers and promotions. He should be able to look forward to a achieving greater heights of recognition in the Industry.

(VI) **Incentives**

Incentive payments should be related to productivity but bonus payments should not be generalised and should be related to the earnings of an individual. In this regard, performance should be judged not merely on productivity, as a particular estate may not have the potential to maximise yield any further.

Management System

The system of Plantation Management in many parts of South East Asia was derived from Sri Lanka, where the Plantation Industry has a history of more than 150 years.

However, some Countries, including Malaysia, have attained sophistication. For instance, apart from Visiting Directors, Planting Advisors, Consultant Engineers etc., larger Companies in Malaysia have set up their own Research Departments, in addition to the National Research Institutes covering various crops. Many of these private Research Departments have developed their own high yielding clones/varieties. Some of these high yielding rubber and oil palm are presently available in Sri Lanka.

An important aspect in this regard, is that Senior Planters who are considered specialists in a field are invited by the Plantation Companies concerned to serve on the planting policy committee of the research Department to advise on such matters as the practicality of implementation.

The full potential and the commercial value of a high yielding clone or variety obtained after years of research depends on the correct agronomic inputs and proper Management practices, implemented by the Planter.

Supporting Agencies

A Planter today is over-burdened with a multiplicity of duties and responsibilities. He is often termed, " Jack of all trades ". In order to afford him to spend as much time as possible in the field to maximise productivity, a number of commonly pooled supporting agencies are available in Malaysia, *viz.* The Malayan Agricultural Producers Association (M.A.P.A.), United Planting Association of Malaysia (U.P.A.M.), East Malaysian Planters' Association (E.M.P.A.), Malaysian Estate Owners' Association (M.E.O.A.) and Rubber Growers' Association Bhd. (R.G.A.B.). There are a number of technical committees of these Associations, Planters are invited to serve on them. This system is one of the main reasons for the success story of the Malaysian Plantation Industry.

The functions of M.A.P.A. are restricted to trade union matters, wages and conditions of service. The aim of the other Organisations are to protect, foster and promote the interests of the Plantation Industry.

The U.P.A.M. is the main liaison body with Government Authorities on non-labour matters. The Planters' Associations of States/Districts are represented at the U.P.A.M. Council at national level. The owners or proprietors are also represented in the Council. Similarly representatives of the local M.A.P.A. Advisory Panels of States/Districts attend M.A.P.A. Council Meetings.

An Estate security scheme established by R.G.A.B. with the blessings of the Police Authorities is in operation under the guidance of District Area Security Advisors. Through the Area Security Advisor in the District who is generally a retired police Officer, it is possible to maintain a close liaison with the Police Authorities in the District. Further the watchmen have been replaced by Auxiliary Policemen who have the authority to arrest even by hot pursuit, detain and question prior to handing over the culprits to the Police for action. This scheme also assists to keep a track of unauthorised persons in the area, thus giving a sense of safety to the residents on the Estate, particularly in the remote areas. What is not required is a show of strength but an intelligensia to complement and assist the Law Enforcement Authorities. The introduction of such a system in Sri Lanka, would in the present context effectively meet the demand for a para-military force, made by the Trade Unions in the Plantation Sector.

The functions of the above Organisations were covered in Sri Lanka by the Planters' Association (P.A.) and the Ceylon Estates Employers' Federation (C.E.E.F.). In fact, the last Executive Vice-President of the Malayan Planting Industries Employers Association (M.P.I.E.A.) and the 1st Director of M.A.P.A. (successor to M.P.I.E.A.) was a former Secretary of the C.E.E.F. In Sri Lanka, currently there are no commonly pooled supporting agencies.

Trade union legislation

Malaysia has evolved effective labour and industrial relations laws. This is one of the main factors that led to the success of the Plantation Industry. Legislation restricts organisation of trade unions to a particular trade occupation or industry or similar trades, occupations or industries. Hence, there are two main Unions in the Plantation Industry, *viz.* National Union of Plantation Workers (N.U.P.W.) and All Malayan Estates Staff Union (A.M.E.S.U.) for the workers and staff respectively.

M.A.P.A. has succeeded in bringing about uniformity in wages and terms and conditions of employment throughout the Industry. It has further minimised areas of friction at Estate level and between Companies and even between the Planters and the workers. The Regional Industrial Relations Officer (I.R.O.) and Unions sort out most of the labour and industrial relations problems. Wages and terms and conditions of employment are decided at National level. All Agreements are incentive orientated with a profit sharing element included. In the case of rubber there is a fixed basic daily wage with two other main components ; one being incentive payment for latex brought in beyond a stipulated minimum per day and the other a price bonus which varies with the prevailing price of rubber. The incentive payment also varies with the prevailing price of rubber. Some of the more important Agreements currently in force are as follows :—

(i) Rubber Tappers Agreement — applicable to tappers.

(ii) Oil Palm Harvesters Agreement — applicable to oil palm harvesters and loaders.

(iii) Cocoa Harvesters Agreement — applicable to cocoa harvesters.

(iv) Coconut Harvesters Agreement — applicable to coconut harvesters.

(v) Palm Oil Mill Agreement — applicable to palm oil mill workers.

(vi) Central Installations Agreement — applicable to workers in rubber factories.

(vii) Fringe Benefits Agreement — applicable to all workers.

(viii) Field and General Workers Agreement — applicable to such workers in all crops.

(ix) Retirement Benefits Agreement — applicable to all workers.

These Agreements do away with the situation of Planters acting on their own an setting precedents. Further, they have ample time to concentrate on increasing productivity.

Staff terms and conditions of employment are covered by an Industrial Court Award.

Productivity

It is a well documented fact that for the achievement of high productivity, close co-operation and understanding between the Employer, Employee and Government is important. In Malaysia, this is a reality to a large extent.

At this juncture, it will be prudent to have a comparative look at the development and productivity of the Plantation Industry in Malaysia and Sri Lanka.

The major crops in Malaysia are rubber, oil palm, coconut and cocoa whilst in Sri Lanka, they are tea, rubber and coconut. The overall hectarage and yield per hectare in Malaysia in respect of the crops have been on the increase whilst in Sri Lanka, there had been a small decrease in the area developed and a decline in yield profile. The area under some of these crops, total yield and yield per hectare, between 1971 and 1983 are presented in Figs. 1, 2 and 3 respectively.

Though in Malaysia, (Fig. 1) the hectarage under rubber has been stagnant, the hectarage under oil palm and cocoa have increased tremendously. The low preference for rubber against oil palm is due to the larger profit margin per unit area and the quicker returns. Furthermore most of the areas marginally suitable for rubber have been replaced with oil palm. The same cannot be said for Sri Lanka (Fig. 1) as both the hectarage under rubber and tea have remained unchanged. Similar trends can be seen in respect of total yield form the various crops (Fig. 2). Another important aspect to note would be that, the difference in yield per hectare of rubber between Malaysia and Sri Lanka (Fig. 3) is widening.

Privatisation of management

Although the basic concept of nationalisation was to benefit the Country, it may be timely to assess the results so far achieved. Low productivity in any area of economic

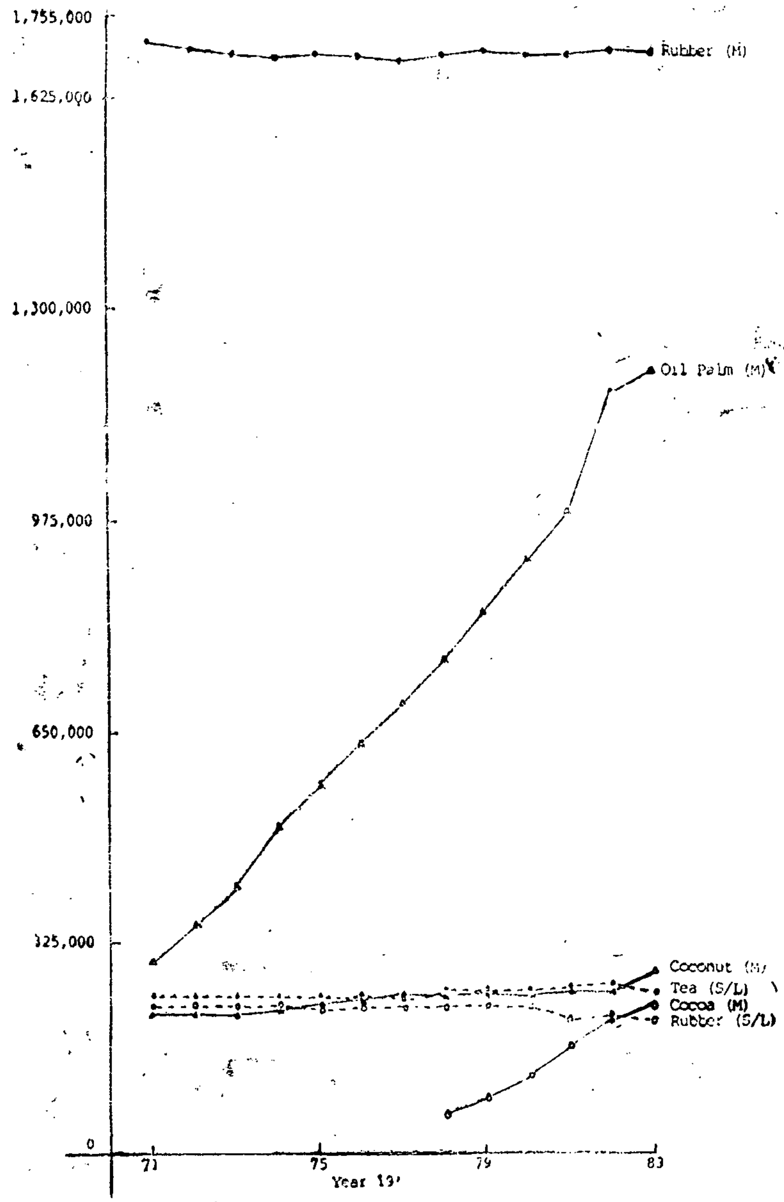

Fig. 1. Source of data for rubber, oil palm and coconut for Malaysia - United Planting Association of Malaysia Annual Report 1983. Pg. 54.

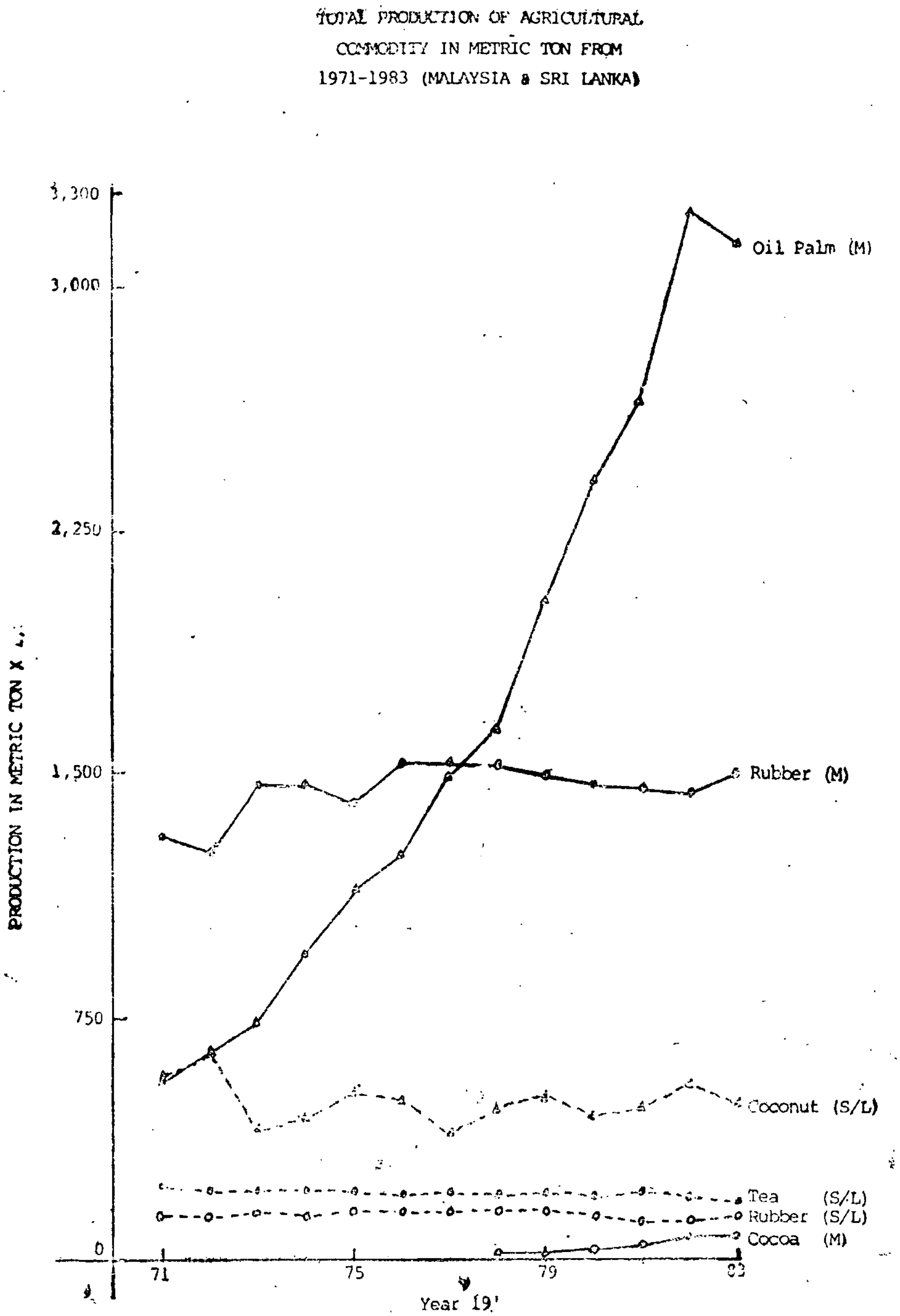

Fig. 2. Source of data for cocoa for Malaysia – Malaysian Cocoa Growers Council Annual Report 1983. Pg. 20.

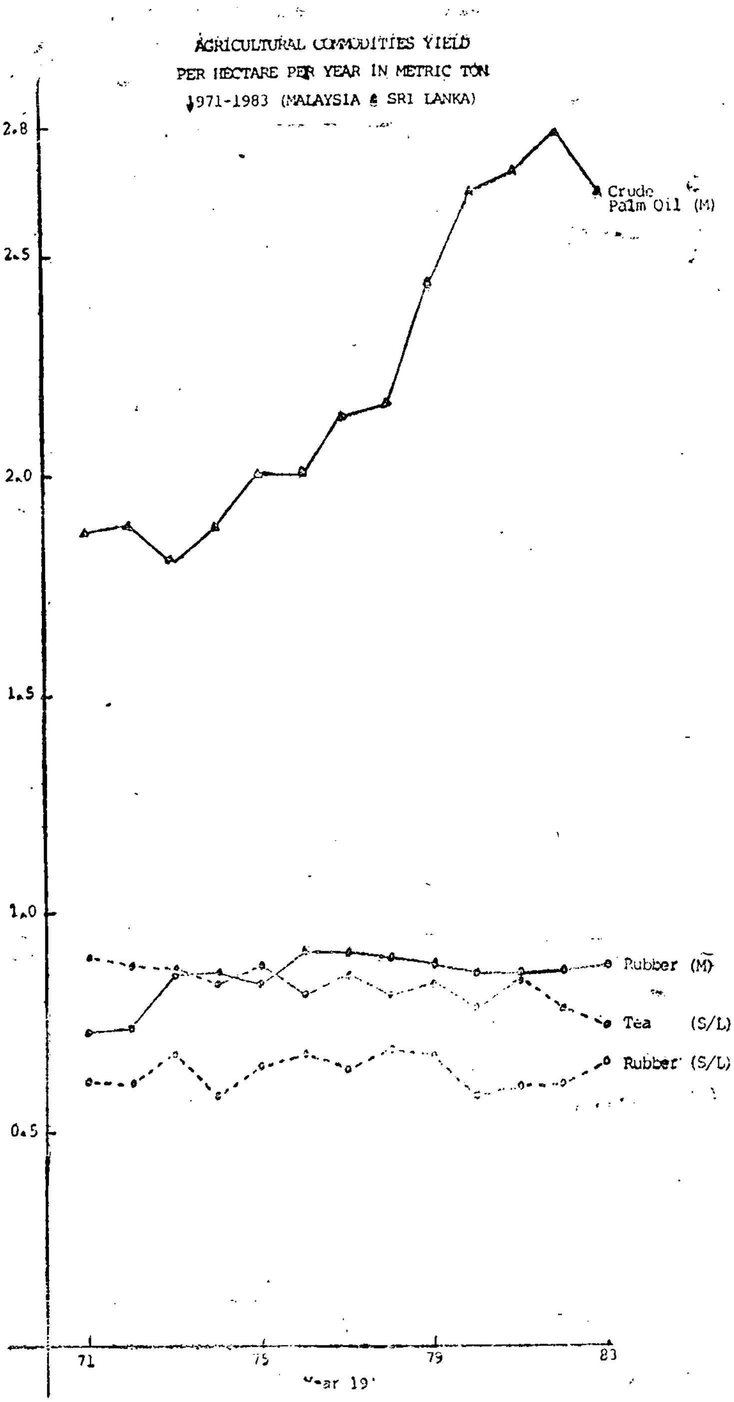

Fig. 3. Source of data for tea, rubber and coconut for Sri Lanka – (Pers. Com.) Forbes & Walker Ltd., Sri Lanka.

activity is unhealthy for any Country, particularly so for a developing Country. Sri Lanka should re-assess the position to ensure that the Plantation Industry is set on the right path, so as to ensure that Agricultural Commodities the base of the National Economy can remain competitive in the world market.

One of the most essential elements to maximise productivity is effective, independent and efficient Management. The Prime Minister of Malaysia has this to say on Management :—

> " There is hardly an Industry in which costs cannot be lowered in one way or another. If careful analysis is made, wastage and inefficiency will certainly be discovered. From then on, it is a question of *good* Management ".

It is heartening to learn that in recent years (Pers comm), there appears to be new thinking with regard to Plantation Management. This augurs well for the future of Plantation Management in Sri Lanka.

Nevertheless, it is prudent to consider re-privatisation of Plantation Management retaining a Central Board devoid of political intervention. Though the Plantations will be managed by private Companies or Agency Houses, the Central Board would be vested with the authority to ensure that the policies adopted by these Companies or Agency Houses are in line with Government Policies, such as :—

(i) Decision on the most appropriate crops, based on the suitability of the land, agroclimate and social requirement of the region.

(ii) Decision on the most appropriate intercrop based on the suitability of the land, agroclimate, micro-climate and social requirement of the region.

(iii) Marketing policies to ensure maximum profitability.

(iv) Legislation providing welfare facilities like housing, education, medical, etc. to the workers.

(v) Ensuring that there is sufficient interaction between Estates and the neighbouring villages.

Privatisation of ownership

In Malaysia, privatisation is being positively undertaken. Some Government Departments such as Television Stations, Railways, Telecommunications and Public Works are being contemplated for privatisation to improve efficiency and productivity. The Government has given an assurance that employees' interests will not be adversely affected in the process. Their future prospects would depend on their performance under privatised Companies. Many other Countries are also actively encouraging the privatisation concept. This may be food for thought for the accelerated development of Sri Lanka.

In this context as the agricultural investment possibilities could be low on account of land ownership limitation, with the establishment of a Stock Exchange the Government could encourage equity participation from the private sector and the public as a whole. The funds derived could be used for further Plantation and other related Developments.

Planter tomorrow

In the Plantation Industry, another important element is the Planter ' The Man on the Ground ' who is vital to ensure the achievement of set targets and to maximise productivity. Thus, as part of any reorganisation the following aspects could be considered :-

Harnessing of Expertise

In Sri Lanka, there is no shortage of experienced Planters, some of whom are in retirement. They are or may be operating on a very low key due to lack of recognition or for various other reasons best known to them. These sources could be harnessed to build up a core of Planters of good quality and also to undertake training programmes for Cadets as well.

Selection of Personnel

Selection of key personnel is of paramount importance, particularly in the Plantation Industry. This need not be over emphasised. Tertiary academic-qualification should not be taken as the sole criterion for selection of Plantation Executives although this would be an added advantage, particularly with rapid advancement in science and technology. Some of the essential qualities to be considered are :—

(i) Readiness and suitability to lead a life in a secluded environment away from urban comforts.

(ii) Communicational ability.

(iii) Alert and quick thinking quality.

(iv) Ability to organise.

(v) Qualities of leadership by example.

Motivation

An important aspect of management is motivation. Due recognition motivates a person to give of his best to maximise productivity. Remuneration alone, although important, does not provide job satisfaction. In this regard, regular visits by Directors from the Head Office to the Estates provide an opportunity to discuss problems and innovations *in situ*. A word of encouragement at such visits will no doubt be a morale booster to the Planters' initiative and drive. The recognition of a job well done can be no better booster of morale to a planter. Above all, such visits would also enable the Hierarchy of Management to judge the Planters perfor mance on the ground rather than solely through reporting arms.

Exposure

A forum for discussion and exchange of views is an aspect that should be encouraged. This would allow Planters to learn and understand each other's problems. Government officials in the District and personnel from research and technical bodies connected with the Industry could be invited to such a forum which would be useful in bringing about better mutual understanding and would solve problems expeditiously.

Such exposure of young Planters would assist in formulating their thinking on administrative matters. Besides building up their self confidence, such fora will also give an opportunity to the Management Hierarchy to identify potential Leaders for their future requirements.

Concluding remarks

A good Planter is not only required to know the technical knowhow of planting and increasing productivity but he should also be required to know, among other things :—

(i) Principles of Management.

(ii) Labour Relations (including a working knowledge of Labour Laws, employee development and training).

(iii) Financial Procedures and Physical Resources.

(iv) Productivity.

(v) Public Responsibility and Community Relations.

(vi) Security of Crops and Property.

(vii) Knowledge of other relevant Laws relating to land, taxation, safety, etc.

To carry out these responsibilities well, he must be able to have a sound mental and physical state, as Oomen Mathew (1984) defines " Management combines man's mental efforts to identify, organise, decide, act and evaluate ". Such a group of Planters can be called as a group of people " who know, because they know" (Taylor, 1984), from the experience gained on the field. There is no substitute for experience.

Every action, they say, has a reaction. Improve " The quality of life " to quote the words of His Excellency the President of Sri Lanka — whether it be that of the Planting Executive or that of the worker at the lowest level — and the quality of the Plantation must necessarily improve.

Foreign financial aid will be useful to improve facilities on the Plantations but Expatriate Consultants are not required to improve Management, as Managerial Expertise of the former Agency Houses is available among the Sri Lankans.

Finally, let it not be said that Sri Lanka which mothered and nurtured the Plantation Management in South East Asia has now been left behind by its siblings. It is never too late to regain that eminent position. It is with will and determination of those in power that this can be achieved.

I thank Kuril Plantations Sendirian Berhad for the facilities afforded me to present this paper, and state that the views expressed in this paper are my own and does not reflect that of my Company.

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RESEARCH REQUIREMENTS FOR THE RUBBER INDUSTRY

By

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Dr Peries — Director Rubber Research Institute of Sri Lanka, Scientists and Heads of Divisions of this Research Institute, Technologists and Research Personnel from the premier rubber growing countries of the world, Chairmen and Directors from the Nationalised Plantation Organisations, Superintendents and Assistant Superintendents of estates administered by the Sri Lanka State Plantation Corporation (SLSPC) and JEDB distinguished visitors, ladies and gentlemen.

It gives me great pleasure as a Chairman of a Regional Board in one of the State Organisations to address you today on the subject of " Research requirements for the rubber industry ". Prior to my isolating and evaluating the research requirements I should pay a tribute to the Director and the Board of the Rubber Research Institute of Sri Lanka for giving me this opportunity to express the views of the producer — and also to extol the first class job done by the team from the RRISL for the organisation of this most successful Symposium — which brings together under one roof the hierarchy that guides the destinies of the rubber industry in the International arena. The importance and significance of Symposiums of this nature cannot be expressed in words as unless such International Conferences become more frequent and conclusive — this massive Plantation Industry can be submerged ere long by the competition from technological development in the fast expanding synthetic field — which now appears to be over shadowing and substituting all that is natural. I am certain that most of those gathered here are aware of the conclusions drawn during the past few years that rubber is the crop for the future and the financial profitability ' Boom " from this crop is just round the corner. But my contention is that possibly due to inadequate agitation and interest by those who constitute us from the natural Rubber World — this anticipated boom and prosperity is still to come and will it ever come is the question. In consequence, natural rubber growing is definitely much less profitable today than growing the parallel plantation crop tea.

Hence, if this trend continues — and we are still lethargic and complacent as we have been — then crops like tea and oil palm will takeover from this great natural rubber industry in the world which has gone on uninterrupted for decades. Prior to my talking on the " Research requirements for the rubber industry " let me in brief evaluate and commend the RRISL and its affable Director — Dr Peries for the very successful manner in which he conducts his activities at the Institute — and also for the aspect of ' working together ' evinced and projected by him in all deliberations and decisions between the Research Scientist in the Institute and the practical Rubber Planter on the Plantation. This aspect is very important when only scientific technology and research can be effectively disbursed through the channels of the working Planters to the media of propagation — the Plantation itself.

RRIC 100 series clones.

To talk in brief of the effective break-through in research already obtained — I think the foremost should be the selection and isolation of the clone RRIC 121 which I am told is resistant to the dreaded 'South American' leaf disease — generally when a clone is isolated for a certain individual characteristic the aspect of yield depression on same is accepted. But the break-through in this instance is all the more commendable as I am told that RRIC 121 is also high yielding as the other isolated clones of the RRI — 100 series. Sri Lanka still holds the majority of its plantations in the PB86 clone — which is susceptible to this South American leaf blight.

Advantages — coming to bearing early 5 — 6 years — high yielding and tree itself is generally robust and sturdy and generally resistant to disease.

Soil foliar analysis

Fertilizer applications, curtail expenditure on fertilizer applications, correct nutrient level maintenances— whilst maintaining high yields as well. Approximately 30% cost saving on fertilizer. For large organisations this is a substantial saving.

Effective Chemicals

Nexobleach — RRISL — water soluble bleaching agent, no smell and non pollution prone in consequence — Chemical Engineering Division should be commended.

Collar protectant for Fomes. Effective advisory and research discovery resulted in Fomes now not being a serious problem from what it was — control and incidence reduced. Also back rot — *Phytophthora* eaılier problematic now no problem. Same with *Oidium*, *Phytophthora* leaf disease etc.

Green budding and polybags

Problem of no seed for 1986 planting season. 1983 planted runts and 85 seed — green bud for 1986 planting. Polybags—Plant and bud with clearing plants and use for resupplying of vacancies in the field about 10 — 15% — uniformity of clearings by gaining the 1 year in the clearing.

Tissue culture

RRISL has practical problem of inadequate finances to progress in expensive tissue culture for plant propagation. Government should release more finances on an isolated programme of priority to help keep pace with Research and Technological Development as evident in other countries.

Recommended research requirements

1. Marketing of products manufactured, presently no market for sole crepe. Biggest producer in World of sole crepe. Marketing Institute for rubber and rubber products, diversification into other products — block rubber, no subsidy for Alfa Laval Centrifuge Separators and bowls — departments relevant should help and encourage diversification to new end products and not discourage those that desire to divresify to new products.

2. 65% Smallholders and 35% of Nationalised Plantations JEDB and SLSPC. Rubber smallholders products have to be perfected by better systems of manufacture and technology to eventuate in a quality export product in the consumer accepted form. Presently bulk, manufactured to only RSS. Encourage to give latex to large Government Plantations RSS — who should like in tea be advised to pay a remunerative rate for latex given on a predetermined formula.

3. Sri Lanka rubber sent abroad and we buy rubber based products. This is a pity —open and encourage greater rubber based product manufacture in Sri Lanka— Free trade zone (FTZ) etc. Offer worthwhile subsidy for import of relevant machinery Alfa Lavals etc.

4. Exchange and sharing of Rubber Technology and Research for advantage of the International rubber growing countries and not frog in well attitude. Exchange RRIC 100 series clones with say latest PB Clones from Malaysia. 3,000 Kg/ha 100, 102, 103, 104, 117, 121, 131. (International Rubber Research and Development Board—IRRDB)

5. Further reduce the period of immaturity.

6. Stimulants and stimulation to derive weaker yields in shorter period and thereafter uproot and replant advantageous today with increased wages.

7. Further development on rubber machinery which have in effect remained unchanged.

8. Indonesians use Michie Golledge knife and tap 500 trees on S/2 d/2 system. Malaysia uses the Gouge knife & taps 500 trees, Sri Lankans use the Michie Golledge knife & taps on 250 trees. Why ? RRISL and all others should investigate and move towards achieving higher task; will result in more latex whereby harder work for greater prosperity of the workforce like in Malaysia cars—motorcycles etc. eventuate in worker welfare will then not need subsidising as is done now.

EFFECTIVITY OF RESEARCH AND ITS IMPLEMENTATION IN THE INDUSTRY

By

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This, the 75th year of the foundation of the Rubber Research Institute of Sri Lanka is a opportune moment to review the effectiveness of Research done by the Institute.

Broadly the research undertaken could be classified as being of a purely scientific nature and research undertaken to solve specific problems which arise from time to time.

The first *i.e* purely scientific research from a practical point of view could be said to be of limited use in an industry such as the production of rubber. But, such a statement, it could be said is not wholly acceptable. Any research undertaken which results in expanding the knowledge of a product could be said to be useful. Such research may at the moment, it is done, be purely of scientifie interest but in the course of time such research can become the spring board on which more practical research could be done. We then come to research undertaken to deal with specific problems and here the record of the RRISL is indeed enviable. In plant breeding, tremendous strides have been made in developing high yielding clones. The RRIC 100 series, is second to none when compared with clones bred in other countries. The IRRDB plant breeders have endorsed the suitability of the RRIC 100 series for large scale planting in Sri Lanka.

On various tapping systems progress has been made which confirm the superiority of the s/2 d/2 system which is in wide use. Also experiments are in progress on puncture tapping and stimulation using Ethrel. Coupled to the tapping experiments research is being done on sensitivity of various clones to Brown Bast. These experiments have given a rich yield of results and the proposal to continue with them would be of immense benefit. This year has been particularly wet and the experiments on the use of rain guards should give us useful information. Research on the stock-scion relationship, we are informed have not given any significant result. On the other hand crown budding, was observed to have resulted in significant yield increases.

Raising of plants in poly bags has indicated significant growth gains, but general implementation of raising plants has been rather slow. Green budding coupled with poly bagging has achieved near 100% success, when compared with bare root stump planting. Another advantage is the evenness of growth obtained with poly bag plants.

The Plant Pathology Department continues investigations into *Oidium* and *Phytophthora* leaf fall, barkrot and the susceptibility of various clones to these diseases. General findings have not shown significant variation. A cause for concern has been Bird's eye spot caused by *Drechslera heveae* in seedling nurseries especially during periods of drought. Research is continuing on control of these diseases.

What has so far been mentioned are just a few avenues of research conducted by the Plant Pathology Department.

Significant advancement has been made on plant nutrition. Research programmes are being conducted into response of rubber trees to fertilizer, economics of fertilizer application, foliar analysis and the influence of leaf nutritional status on latex yield. The importance of cover crops together with developing analytical methods for the study of mineral nutrition. Fertilizer application is now based on soil and foliar analysis and significant savings have been possible on in-puts of fertilizer. The advantages of leguminous covers on the growth of the rubber plant are being evaluated. In this connection, mention should be made of a variety of winged bean which has been developed and could be grown as a cover crop. This is a significant break through as in developing countries where protein is always in short supply, this could prove to be a cheap alternate source. Further research into this would be of tremendous benefit not only to the rubber industry but to the people of this country as a whole.

Today, we apply 100% urea based mixtures. The Planter himself both tea and rubber viewed this trend with misgiving but experimental evidence indicates that such fears are unfounded. Economically, even if we apply an additional 20% on the recommended dosages, there would be still a tremendous saving. However, experiments are being continued on the use of urea together with the effects of P, K and Mg on growth.

Special study is also being conducted on the application of NPK to ground covers and in most instances it has been established that in general growth of trees in legumes is superior to that in naturals.

Recently, a major break through was made in the development of a water miscible bleaching agent commercially marketed as New Nexobleach. The research conducted by the Rubber Chemistry Department on liquid natural rubber, CV rubber, skim and cyclised rubber have proved to be of immense benefit. The various commercial uses of NR are being evaluated and expanded. The Biochemistry Department we are given to understand is investigating into the causes of brown bast, which incidence planters view with concern.

Inter-cropping is a subject which continues receiving close attention. Bananas, passion fruit, pineapple are some of the crops being inter planted. The inter-cropping of papaw has not been quite satisfactory. Planting of pepper between immature rubber is in experimental stage and it is still too early to fully evaluate. I have already touched upon the growing of winged bean (Dambala) as a crop. Cocoa in rubber is nothing new and further experimentation would be of tremendous financial benefit.

The fore-going are just a few examples of research which has been done. The impact of such research has been significant in that by developing high yielding clones, production should increase. Also with such increases cost should come down. The discovery of suitable bleaching agents has kept the crepe industry viable.

For any research to be truly effective, there should be early and wide spread dissemination of information. Here perhaps it could be said there have been delays or a breakdown in communication. It is normal when anything new is promulgated that such findings are slow to be accepted. Immediately following nationalisation of estates and the creation of multifarious state organisations to manage these estates there was a breakdown in communication between the Research Institutes and the management. However, since 1977 with most State managed plantations coming under the umbrella of the JEDB and the SLSPC, once again useful dialogue has been established between the Research Institutes and the planters. It is not unusual to now see teams of Scientists visiting factories and fields, attending meetings of planters, conducting work shops for members of the field and factory staff, in order to give of their knowledge to those who would ultimately put it into practical use at the very grass root level. This dissemination of information has already had an impact in bringing about a transformation in nursery techniques in the field and in improving the general standard of manufacture. Development programmes are also being drawn, harnessing the invaluable wealth of knowledge and experience available in our Research Institutes.

There is one other matter which I would like to touch upon, namely Market Research and Intelligence. This may be outside the purview of research conducted by an Institute such as RRI but market intelligence is an essential ingredient for future research and without such information it is not possible to plan a strategy for the future development of the crop in Sri Lanka. Today we produce the best crepe rubber in the world, which is the highest grade of NR available. Little information is available on its end uses. Why does Russia suddenly pull out of the market and why have the USA and UK which were the main consumers of crepe rubber reduced on their purchases. It would be relevant to mention that a country such as Malaysia has 15 Bureaus in the world, which feed back to their producers and Research Institutes the demand for various types of NR and even go to the extent of arranging direct sales, between the producer and the manufacturer of the end product. The greatest competitor of NR is SR. It is up to us to take the battle into areas which has been solely dominated by synthetic rubber. This can be done with correct market evaluation and with new methods of processing NR to meet specifications required. You will therefore see the link which could be established between market research and intelligence and the expanding use of NR into avenues which have been the sole preserve of synthetic rubber.

Recently we had one of the major buyers from the continent visiting factories in Sri Lanka and following discussions with him a rubber was produced which he felt could be used exclusively for medical purposes. Certain specifications and guarantees had to be given and with the assistance of the RRI this particular type of rubber was manufactured which gave us a premium price of Rs. 1/- per kg. over and above the top IX price.

In concluding I quote from Dr O. S. Peries's Annual Review for 1980. Therefore the policy makers the top management on estates the advisory services to small holders and the Research Staff of this Institute have a duty by this country to develop NR to be the top money earner for Sri Lanka. This can be done. It only needs clear thinking, bold planning and the will at the top to ensure that the plans are implemented.

13th September, 1984.

THE PROBLEMS AND PROSPECTS OF THE RUBBER INDUSTRY IN SRI LANKA

By

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Sri Lanka was the fourth largest producer of Natural Rubber for a long time, next to Malaysia, Indonesia and Thailand and in 1970 produced the maximum ever at 156,644 MT. Production gradually declined thereafter and in 1982, we produced only 128,144 MT while India with 165,000 MT and China with 140,000 MT, pushed Sri Lanka into the sixth place in the world Rubber Production Arena. The decline in production is attributed to numerous reasons, such as nationalisation, backlog in replanting under the Subsidy Scheme, decrease in extent and also poor prices for RSS, which discourages the smallholder from maximum exploitation of his trees.

70% of the extent under rubber in the island is still under private ownership and of this 54% consists of smallholdings. Therefore, the State Organisations control only 30% of the extent under rubber. 11% of the Country's export earnings is from rubber, which is equivalent to 4% of the Government's budgetory revenue. 87% of the production is exported and only 13% is utilized by local industries.

Forecasts by experts indicate that global output of rubber would increase annually at the rate of 3·6%, while the demand would grow at 4·8%, thereby assuring a steady demand for natural rubber.

Sri Lanka will also endeavour to take advantage of this increasing demand for natural rubber. New development programmes have been formulated under the Medium Term Investment Programme for State owned estates during 1985/89, when it is envisaged that 12,500 ha would be replanted annually by the Sri Lanka State Plantation Corporation (SLSPC) and JEDB, with high yielding clones, such as the RRIC 100 series evolved by the Rubber Research Institute of Sri Lanka. The private sector will also step up the rate of replanting assisted with World Bank Aid.

The Development Programme also envisages the modernisation of factories and grouping estates to facilitate the operation of central factories, which would concentrate on production of high quality sole crepes and blanket crepes. The demand for sole crepe fluctuates and producers of this grade of rubber are aware of the difficulties they have to face, when suddenly there is no demand or contracts forthcoming. Why should we face such uncertainty ? Is it because we have no control over the marketing strategy ? Should we producers not search for and establish contracts with consumers of this product and ensure a steady supply and demand position at a reasonable price, which would be beneficial to the producer as well as the consumer ? Long Term Contracts, say for a period of 6 months, when 50% of the sole crepe production of an organisation could be offered, could also tend to stabilize prices and assure a steady demand. With the increase in production envisaged, this important factor should receive immediate and serious consideration by the state ; if not, the millions spent on factory development would not achieve the desired result.

Technically specified rubber (TSR) could very well erode into the latex crepe market and here too, long term contractual sales would support the demand for latex crepe.

Latex based products for export

The need to encourage the conversion of raw rubber into value added finished goods for export cannot be over emphasised in order to utilize the increase in production anticipated, as a result of the accelerated replanting programme.

This can be achieved by attracting foreign firms with experience in latex product manufacture and with access to ready markets abroad, to set up industries in Sri Lanka, in collaboration with the JEDB and SLSPC.

Joint ventures have many advantages since they eliminate marketing problems and the need for specialised technical training and also, after a period of time, such joint ventures could become 100% Sri Lankan owned. The basic raw material for such industries is centrifuged latex and this raw material of acceptable quality, should be made freely available to any industrialist, at a fair and competitive price, in comparison to the cost of such raw material in other rubber producing countries.

The present maximum production capacity of centrifuged latex is around 4,000 mt annually, while actual production is 2,500 mt. This should gradually be increased to 10,000 mt since centrifuged latex has an expanding market and is very profitable too. The JEDB is at the moment the largest producer of centrifuged latex and recently have taken steps to double their production. The SLSPC is also exploring the feasibility of setting up a centrifuging plant and it is hoped that their efforts would be successful, in the national interest.

Centrifuged latex should always be produced in amounts greater than immediate local needs, to ensure ready availability of this raw material and in order to continue to attract potential investors into this area.

Supply of centrifuged latex

The raw material for the manufacture of centrifuged latex, as you know, is field latex, which can be obtained from any rubber plantation.

In Sri Lanka, almost all the field latex is processed into RSS, latex crepe, sole crepe and block rubber and at present, only a minute quantity is centrifuged.

The crisis that has now affected the latex crepe industry necessitates the planned diversion of latex normally converted to latex crepe, into centrifuged latex manufacture, thereby controlling the availability of latex crepes in the market, in order to stabilize prices.

As I mentioned earlier, producers of rubber such as the JEDB and SLSPC should earnestly explore possibilities of setting up industries to convert raw rubber into value added finished goods and there should be no difficulty in identifying foreign collaborators.

Their knowledge, expertise and ready markets could be matched with our raw material and inexpensive labour, to achieve a product which would be attractive cost wise.

Smallholders

Very nearly two thirds of the rubber extent in the Island is composed of smallholdings. The Government has assisted these smallholders in numerous ways but such assistance has not had the desired effect in most instances. Although these smallholdings are to be found in and around the State owned plantations, it is unfortunate that the smallholder has not benifitted by the expertise and facilities available on these plantations. Smallholder latex is rarely accepted in our factories due to various constraints. Is it in the national interest to continue in this manner ? With the re-organisation of factories under the MTIP it is suggested that, in each sub-district, a small crepe factory be set apart to handle smallholders' latex.

Perhaps you may be aware that latex crepe rubber production showed a remarkable growth in 1983. This was at the expense of sheet rubber but as a result of this increase of 26,162 mt of latex crepe production over 1982, the country earned an extra Rs. 56 million, and this was achieved without any new latex crepe factories coming into operation, indicating the existence of a considerable unused installed capacity for the production of latex crepe in the plantations.

I would venture to state further, that the smallholder should also be assisted in the cultivation of his smallholding, by the managerial staff on estates in the vicinity, and the local advisory officers of the Rubber Research Institute (RRI) could co-ordinate and assist in planning such measures and inputs. The feasibility of attracting and adopting smallholdings around an estate, on a permanent basis, merits consideration. This would induce tremendous confidence in the smallholder, to realize that perhaps his fertilizer, pesticides and even labour if required would be supplied by the parent estate, while his latex will be purchased at a fair price and the cost of inputs deducted from the income he is to receive. Such meaningful assistance will also help estate village integration and help to bring about better relations and understanding between the estate population and the villagers who live in close proximity.

Scrap rubber harvested by the smallholder is sold for a pittance to the closest rubber dealer who in turn sells it to bigger dealers or to an agent of the owner of a scrap rubber manufacturing factory. Very little reaches the four block rubber factories, since they are working to full capacity.

The State sector should explore the feasibility of setting up small block rubber factories to manufacture SLR 20 with estate scrap and SLR 50 with smallholders' scrap, thereby ensuring that the smallholder receives a fair price for his scrap rubber and also the country would earn extra foreign exchange by converting all scrap into block rubber instead of scrap crepe.

Another factor which affects the smallholder and all rubber producers is the high level of duty that this commodity attracts. Should we not fall in line with other natural rubber producing countries, in this sphere, in order to ensure that our rubber is competitive in world markets, and also to ensure a better income for the producers very specially the smallholders.

GROWING OF RUBBER WITH SPECIAL REFERENCE TO REPLANTING CYCLES

By

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This paper presents the views and observations of a Rubber grower, and sets out to briefly discuss a mutual appreciation of difficulties and responsibilities of the scientist and the grower in making the rubber industry of this country, which is a national assets, as well as a means of livelihood for the many people who are directly and indirectly associated with the industry. There were gloomy forebodings for the future of the natural rubber industry in the 1950's and the competitive pressure exerted by the synthetic rubber industry left no alternative to the natural rubber producer but to embark on development programmes laying emphasis on replanting and improvement in quality. The Government commenced the replanting subsidy scheme in the year 1953 and undertook development of factories, with substantial assistance to the producer. Much encouragement was needed for the producer to undertake this massive investment on development and all of us who were present at the International Rubber Conference held in 1973 in this same venue, would recall the revitalising comments made by Doctor B. C. Sekhar who said " there is a future for Natural Rubber as the Aircraft of the future, the Concord has to land on Natural Rubber tyres ". This remark was greeted with delighted applause and from what we see today, there is no doubt in the modern technical world, there is a need for NR and its has to exist.

It is in this context with a firm belief on the future of NR, I express my views related to the three main categories of rubber growers in Sri Lanka.

Table 1

	*Acreage	Production
Small Holdings (1 — 10 Acres)	260,000	55,000
(10 — 50 Acres)	80,000	25,000
(Over 50 Acres) Mostly State owned Plantations	170,000	55,000 Tons

* Acreage in rubber is being revised

Earnings from Rubber as proportion of total Sri Lanka export earnings is in the region of 14%

Table 2. *Age analysis of rubber lands held by the three categories (acres)*

	Under 10 years	10—30 yrs.	Over 30 yrs.
Small holdings (under 10 acres)	60,000	120,000	80,000
Small holdings (10 — 50 Acres)	10,000	30,000	40,000
Over 50 acres	60,000	50,000	60,000

The first two categories of growers own approximately 67% of the total rubber extent with the balance ownership, held by the state.

The need for replanting in general arise when the economic yields are not forthcoming due to ;

1. Total consumption of exploitable bark.
2. Poor yields due to clonal characteristics.
3. Poor yields resulting from substandard after care of holding/plantation.

A smallholder by virtue of its small extent, is faced with a difficulty in the matter of deciding to replant and replanting itself. These holdings, due to land alienation laws and the connected need for housing, tend to diminish in extent progressively, with the result that the skilled worker employed is driven away. This situation is understandable when it is seen that the total earnings as profit, from a small holding of 1½ ha has been in the region of Rs. 4,300/- per annum in 1983 while the same smallholder if employed as a tapper in a neighbouring plantation would earn nearly Rs. 5,200/- per annum, with the added security of employment and other retiring benefits. With the increase in wages this year, the total earnings would be in the region of Rs. 7,800/- per annum. Thus for him, the alternate employment of less skilled tappers, children and elderly people in the village, would be meaningful to increase his income, but causes a tremendous loss of efficiency in intake and panel care. However this situation is under fair control due to the limited employment opportunities available in the larger plantations. Therefore, when lands are given out to villagers, either from plantations or other crown land to plant rubber, the minimum extent of such allotment has to be determined, based on an evaluation of income per ha. Unless this basic unit is able to generate sufficient income, for the sustenance of the owner, extension services too may prove ineffective. But, when land available for distribution is limited, the other alternative would be to manage rubber lands as large estates, and share the profits.

Therefore, training of tappers needs priority, specially when it is known that the younger generation is reluctant to adopt this vocation, as observed at village level. Of course, all development programmes, where factory work is provided to young people, will always draw to younger workers away from tapping, weeding and other forms of labour, which is considered menial. Malaysia, which is rapidly becoming industrialized is already feeling the effect of this "labour drain".

Low yields from this large extent of land in the hands of the smallholder is causing concern, and a substantial increase in yield is necessary to justify the heavy expenditure incurred as replanting subsidy. Application of a theoretical replanting cycle to this category is not feasible, but a meaningful extension service as provided by the RRI is valuable to inculcate a sense of awareness in their minds, on important aspects of after care of the rubber trees, grown at immense expense to the state and the producer. Under the extension service programme leaders are selected from each area and short term instruction classes are provided on manufacture and cultural practices, and the desired awareness is conveyed rapidly to the village.

Tapping slope and bark consumption which has a direct relation to the replanting cycle is often forgotten. Frequency of tapping is not in keeping with the accepted intensities, inclination to avoid late tapping on wet days and poor stand per acre, are the major causes for the low yield observed. Extension services should cover all aspect of bud-grafting, green budding, polybag planting, tapping, application of fertilizers, and weed control, as the smallholder is unaware of their importance, to increase yields. The low stand per acre is one of the main reasons for low yields in this group, caused by their inability to procure and supply vacancies at the correct time. For example a smallholder having 12% vacancies, in his holding is deprived of nearly 12% from his only source of income, and will continue to do so for the next 20 years. This unfortunate situation can be avoided if they are trained to bring up a few plants in polybags to supply vacancies during the first year of planting.

Owners of the second category (10 — 50 acres) include those who have received their land entitlement from the Land Reform Commission after their statutory determination, form extents of 50 acres demarcated from larger plantations. These are better managed and placed in charge of experienced supervisory grade officers whose emoluments are higher than the earnings of a daily paid worker. Skilled tappers receiving stipulated wages are being employed, and have their independent RSS producing factories. Some of these owners supply their latex to neighbouring crepe factories. Regular application of fertilizers is undertaken in most units, but a planned replanting programme is not effectively enforced. Owners in general are not residents on the estates. This is a problem. Land, and income from it is virtually extra pocket money to some of them. There are the week-end landlords to whom land ownership provides a relaxing weekend hobby. They should however be mindful of their responsibility to the industry.

The third category of lands (over 50 acres) mostly State owned, well managed, with an average yield of over 1,050 kg per ha., (in 1983) and keeping ahead of the national average by a margin of over 200 kg per ha., adhere to a replanting cycle of 30 years Due to the low rate of replanting undertaken prior to nationalisation, in most of the estates, the desired programme has not been implemented. As a result, after nationalisation replanting has been accelerated and in some plantations, the extent in the immature phase is as much as 50 to 60% of the total extent of the plantation. This accelerated replanting programme no doubt will interfere in the implementation of a future replanting cycle of the unit. Perhaps, if replanting is undertaken on a region or district basis, the desired target could be achieved, but the concept of retaining the viability of individual units, may fail for some length of time.

The commonly used clone for replanting after 1953 has been the clone PB 86. It has been observed that most of the plantations have exceeded the theoretical 7 inch bark allocation for the year, and reached the peak harvest in the 18th/19th year after planting. In this situation, after accommodating further 6 years for intensification, uprooting is due on the 25th/26th year leaving a further tapping period of 4/5 years at uneconomical intake levels, when the present 30 year replanting cycle is practiced.

To overcome this position, stimulation is suggested, but our past experience is that the majority of us have not succeeded in obtaining a satisfactory result, due to the weather pattern we experience, and I suppose it is difficult to get through more than two stimulations per year. To meet the challenge of high costs, a shorter replanting cycle seems to be the other alternative, and perhaps this may not be in accordance with the economics of planting. But re-thinking in this direction, seems necessary, when we consider the fact that an income of approximately Rs. 25,000/- per ha is possible from the sale of rubber trees, with the buyer, uprooting and clearing the land free of charge. This is equivalent to an income of Rs. 5,000/- per ha., over a period of 5 years, which again is much more than the annual income from rubber yielding 1,200 kg/ha. With 5% of the total work force of the country employed in the rubber industry the achievement of a economic yield within the shortest possible time is a necessity.

Research on plant breeding is a continuous process where we all know considerable time is necessary to identify and establish a suitable clone with the desired features, and the benefits of this long process cannot be achieved, if rapid replanting is not undertaken. Our scientists have produced suitable clones to meet the situation described above. Selected clones from the RRIC 100 series, with an immature phase of approximately 5 years, giving a satisfactory initial yield and a peak yield of over 2,500 kg, per ha., have been recommended for large scale planting. It is my belief, that a plantation on a 3% rate of planting could afford an increase of 1%, still retaining 80% of the plantation in the mature phase, when the recommended newer clones are used. This increase in the rate would place us in a replanting cycle of 25/26 years, and would greatly assist to clear the backlog of uneconomic rubber at least in the State owned large plantations. After which replanting could be undertaken on a lower note looking forward, hopefully, for an established economic yield for our plantations, maintaining 85% of the extent in production.

Sometimes I may have touched on areas of controversy without sufficient data and statistics. This is intended as I consider it necessary to stimulate deep investigations, and moreover, I cannot think of a better forum than this representative group of scientists, rubber growers, government officials and others connected with the industry, to present my observation.

CONCLUSION

Management skills of the smaller units require further improvement. Formation of Group Management Organisations with sufficient holdings grouped to form units of 10 to 15 ha., managed by a trained leader from the village, utilising trained labour receiving wages applicable to the trade, as a further extension to the existing group processing centers, is advocated and placed for consideration.

A study, preceded by a socio-economic survey of the smallholders of the group up to 10 acres, to identify the causes relating to the low tappings undertaken, low yields, insufficient fertilizer use, and the low net sale average, to be undertaken early.

Accelerated rate of replanting or a 25/26 year replanting cycle for the larger plantations is also a subject for further consideration.

Our eminent scientists who are with us today, have always been in the forefront of the industry, evolve the strategy, for implementation by the producer. We thank them and look forward to meeting the emerging challenges to the natural rubber industry, with equal strength.

CLOSING SESSION

SEVENTY FIVE YEARS OF RUBBER RESEARCH IN SRI LANKA

By

O. S. PERIES

(Director, Rubber Research Institute of Sri Lanka)

Rubber research was started in Sri Lanka in 1909, when some rubber planters in the Kalutara District pooled their resources to engage the services of a British Chemist to study the process of latex coagulation. This was the start of systematic research for a vast industry that now supports millions of people in South East Asia, and is their only source of income. The Rubber Research Institute of Sri Lanka organized an International Conference to celebrate this occasion on 17 – 19 September 1984, this is a summary of the highlights of this Conference.

Tan Sri Dr B. C. Sekhar, Chairman of the Malaysian Rubber Producers Research Association, one of the world's foremost authorities on natural rubber (NR), advised all rubber producing countries to gear themselves to increase rubber production as the demand for the product is going to increase in the next few years. NR producing countries should not miss this golden opportunity to support their economies, because the industrial nations will go in for substitutes, if we default on supplies. He emphasised that synthetic rubber (SR) is only a substitute, a poor one at that, and that it will never be able to replace NR fully. The natural product is a unique material, with many special properties. Every pound of NR that has ever been produced has always been sold, which cannot be said for SR. This shows that it is only when we, the NR producers, fail in our efforts to supply the quantity required that SR steps in to fill the gap.

The present unattractive price for NR is only a temporary phase, caused by recessions in various countries, which has led to a poor demand for motor vehicles, that use up 65 to 70 percent of all rubber, both NR and SR, produced in the world.

When the world economy improves, the sales of cars will increase, and then NR will come into its own. The forecast for rubber demand is in the scale of 18 million tons in the 1990s, and even on the present scale of consumption, this means that at least 6 million tons of NR will be required to satisfy this demand and that calls for a doubling in the present supply position. However, the forecasts are even better, because it appears that from the present situation, of NR supplying 30 percent of the world demand, NR can claim 40 percent of the market, on its techno-economic performance. This will tilt the demand towards NR still further. As far as the price is concerned, on the basic properties of NR and its utility value, a fair price for NR at present would be 1 US dollar per pound. Therefore, the current price for NR is almost exactly half of what it is worth. The reason for this Dr Sekhar said was mainly the poor marketing system for the product. He urged that a new marketing arrangement be developed, with all NR producing countries contributing to the system so that a realistic and fair price be paid for it. The present marketing system is an archaic 15th century arrangement, not in keeping with the present development of the world.

It is difficult to summarize the proceedings of a Conference, where 86 papers were read, in 3 days, on such varied subjects as plant breeding, tapping, fertilizer usage, disease control, climate, smallholdings, soil management, economics, rubber chemistry and technology, energy use and labour costs, in a few minutes. Therefore, let us use the endeavour of the 1984 Olympics : "Higher, Faster, Further" as a yardstick to measure the achievements of research to support the industry – how far have we been successful in developing clones to give higher yields and faster growth, how successful have we been in developing further uses for NR ? This is what I will try to do in this summary.

The NR industry has been singularly successful in developing high yielding fast growing rubber varieties. Sri Lanka has been particularly successful here and four of its recently developed clones have come out at the top of international trials carried out in various countries. There are new clones that have produced 4,000 to 5,000 lb of rubber per acre under experimental conditions – a far cry from the 400 to 500 lb of rubber per acre, produced by the old seedling varieties. Now, these new clones must be adequately looked after, fertilized, protected from pests and diseases and be tapped according to scientific standards-clearly laid down. The NR research studies all over the world have made numerous advances in all these areas. The current trend is towards labour saving devices for tapping and this is engaging the efforts of all countries, due to the rapidly escalating cost of production. All fertilizers, in general, are imported into all NR producing countries. Therefore, there has been a concerted effort to reduce nutrient costs – the use of the soil and foliar analysis technique for fertilizer usage on rubber has reduced costs of *Hevea* nutrition by at least 30 percent in recent years, a very significant contribution to the economy of the industry. Disease control is taking a very definite path towards biological control of all leaf, stem and root diseases and a number of scientists showed their success with this technique, where only the minimum quantity of fungicides and insecticides are used to preserve the health of the tree. It was also noted with great satisfaction that Sri Lankan scientists at the RRISL were the acknowledged leaders in the field of *Hevea* pathology.

The papers on marketing and economics were extremely interesting, as they brought out the interesting aspects of the manner in which the world rubber market operates, its strong and weak points. It was agreed that Sri Lanka should allow forward sales of rubber up to at least 6 months ahead. The restriction of this facility at present, acted to the detriment of our country. As far as economies of rubber growing are concerned, a very interesting paper from the School of Economics in the Australian National University, clearly showed that, when countries took steps to bring in laws to control the amount o earnings that a grower received from his crop, the result usually was almost always opposite to what the country wished to achieve. For example devaluation is a case in point. Theoretically, devaluation should increase the local value of commodities like rubber. However, the real result of devaluation is generally to increase the price of all goods in the country, with the result that the smallholder is ultimately worse off than when the process was started. Therefore, all economic measures taken, with the very good intention of helping the local population, must be studied in detail to ensure that the legislation enforced will achieve the results expected. Economic theory alone is not sufficient.

The NR industry has made several advances in the field of enlarging the scope of the use of rubber. Some 32 papers were read on the diverse subjects of manufacture of commercial goods, raw rubber manufacture, and properties, chemical modification of NR, NR technology and analysis, compounding and ageing properties, latex concentrates alternate sources of energy and environmental pollution and its control. All these studies have helped to improve the properties of NR, with a view to increasing its price. However, this is the one area of this industrial raw material, that gives a gloomy picture at present. As stated at the beginning of this summary, the value of NR should be about 1 US dollar per pound ; but it is now selling at exactly half that price. That is the tragedy of the world, that the industrial nations can always dictate the terms of trade to the underdeveloped countries. If we take any plantation crop, the picture is the same. The basic problem in agricultural production in the developing world is that the price paid for the product is always so low that all that the population of developing countries can expect is to eke out a subsistence living. Taking comparative numbers, if a person in the developing world could buy a tractor for 500 bags of coffee in 1950, then he cannot hope to buy a tractor today for less than 50,000 bags of coffee. The cost of production of the tractor has gone up, admittedly ; but so has the cost of production of coffee. However, there is no consideration of this in the international market. Instead, there appears to be a tacit acceptance amongst the people of the developed countries that the labour in developing countries should live on a subsistence diet, just to enable them, the haves, to maintain a high standard of living. This is the reason why certain labour intensive industries keep moving from one country to another. As soon as labour costs go up, then industries move to lesser and lesser developed countries. Is this fair ? All I want to emphasise here is that the prices of commodities will not reach equitable levels, until and unless all nations in the world accept that we are all a part of the world community of people. None of us owe the other a living ; but we all certainly owe the other a fair price for his labour. If this is accepted and acted upon, then we will have a fair price for rubber, as well as coconuts, tea, cocoa, oil palm and all the other primary products in the world. The Finance Minister of Sri Lanka, Mr Ronnie de Mel always points out that there is nothing called a " free meal ", so that all of us must be ready to work for our rice and curry. But equally, it must be accepted that there is nothing called " free labour ". All labour must be paid a fair price. We are not asking for a 3-car family ; all we are asking for is a 3-meal day. I wish to leave you with that message, and all you nice people from abroad, I should be grateful if you carry that message back with you to your countries and your people. Thank you.