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ON SOME BIASES IN THE GENERATION OF TECHNOLOGIES BY RUBBER RESEARCH INSTITUTES

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SUMMARY

This paper considers the distortion in economic use of resources flowing from the generation of partly inappropriate techniques and technologies. This distortion comes especially from the application of techniques essentially developed for estate conditions to the situation of smallholdings. As an introduction to the paper some pertinent economic concepts are discussed.

A review is made of past research in the major rubber-producing countries, and highlights the almost exclusive concentration until recently on techniques and technologies suitable for estate conditions. Some specific examples of bias are reviewed in detail and desirable economic adjustments, in application to the circumstances of smallholdings, are suggested. The examples of major concern involve research on tapping systems, and on planting methods including the specific aspects of tree planting densities, intercropping and weeding. There is also the overall problem that the basic levels of input use on rubber research stations are usually inappropriate to realistic experimentation on the problems of smallholders.

It is believed that a better adaptation of available techniques and technologies to the situation of rubber smallholdings can produce substantial economic benefits.

INTRODUCTION

A technology may be defined as the body of existing knowledge concerning the production of a particular commodity from the appropriate inputs (or resources). A technology may be described by quantifying the relationship between the output of a commodity and the amounts of the various inputs needed to produce it. A simple illustration of such a relationship, between the output of a particular crop and its inputs of 'capital' and 'labour', is given in Fig. 1. Here 'capital' inputs may be taken to include such items as buildings, equipment, fertilizers, weedicides, and liquid working capital. 'Labour' may comprise both family and hired workers. 'Land' is omitted from this consideration, but may be assumed to be 'fixed', in that the different quantities of capital and labour are all combined with a fixed quantity of land, be it in hectares, acres, or some other unit.

The curve Y*Y* (Fig. 1) denotes the varying combinations of 'capital' and 'labour' inputs (as measured on the vertical and horizontal axes respectively) which may be used in producing a given output Y* of the particular crop. Thus at point A, for example, Y* may be secured by using 7·00 units of capital and 2·50 units of labour ; at point B, on the other hand, Y* may be secured by using 4·00 units of capital and 5·00 units of labour. A curve such as Y*Y* is generally termed an 'isoquant'. Fig. 1 illustrates that under normal circumstances a given technology does not merely involve a single unique combination of inputs in producing a certain output ; rather it embraces a whole range of different possible combinations. Particular unique combinations of inputs within the technology, such as those defined by points A and B, are customarily referred to as techniques.

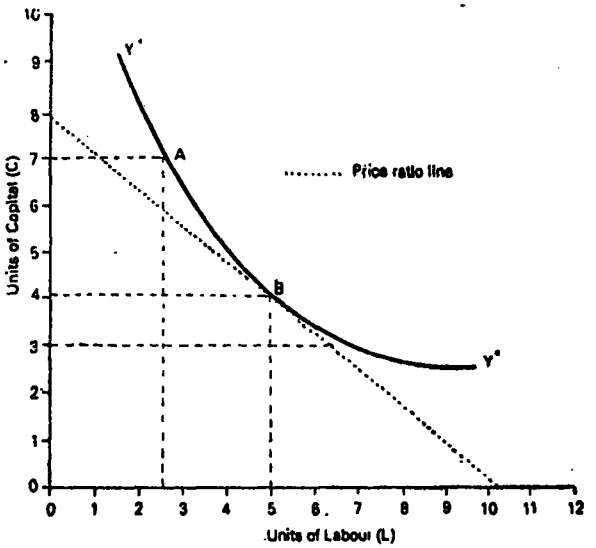

Fig. 1. Description of a Technology.

An important question with such a technology is to choose that technique which minimizes the combined costs of the inputs. In respect of possible combinations between capital (C) and labour (L), this is the combination where the marginal rate of substitution between these inputs is equal to the inverse ratio of their prices, PC and PL. Symbolically, this is the combination at which

$$-\frac{dL}{dC}=\frac{PC}{PL}$$

where $\frac{dL}{dC}$ is defined as the marginal rate of technical substitution between capital and labour. The reasoning behind this conclusion is explained by innumerable textbooks of economics, for example by Henderson & Quandt (1973) or by Upton (1976). The technique representing the 'least-cost combination' of capital and labour in Fig. 1 is at point B : this is where the line denoting the price ratio between capital and labour is at a tangent to the curve Y*Y* indicating the changing marginal rates of substitution between these inputs. The first major argument of this paper is that the techniques being developed and recommended by the publicly financed rubber research institutes are often not economically optimum according to the analysis just outlined, and are generally biased towards an undue usage of capital inputs. This argument is pursued in detail below.

A change in technology may be defined as a change in the body of existing knowledge concerning the production of a particular commodity. Such a change will involve a process innovation, an improvement in technique which reduces the average costs per unit of output despite the fact that input prices remain the same. A cost reduction of this nature implies that the average productivity of at least one of the appropriate resources is increased. Technological change may also involve

some modification in the form of output, which serves to improve it ; this is termed a product innovation. Some major features of a change in technology through process innovation are illustrated in Fig. 2.

The isoquant $Y_0{}^*Y_0{}^*$ (Fig. 2) denotes the technology in the 'original' situation, before any change takes place. Any positive change from this situation must involve a movement of the isoquant from its original position towards the origin 0. Three possible movements which are useful to distinguish are those to the respective positions of $Y_1{}^*Y_1{}^*$, $Y_2{}^*Y_2{}^*$, and $Y_3{}^*Y_3{}^*$. It is assumed here that the price ratio between the units of capital and labour remains constant during these changes.

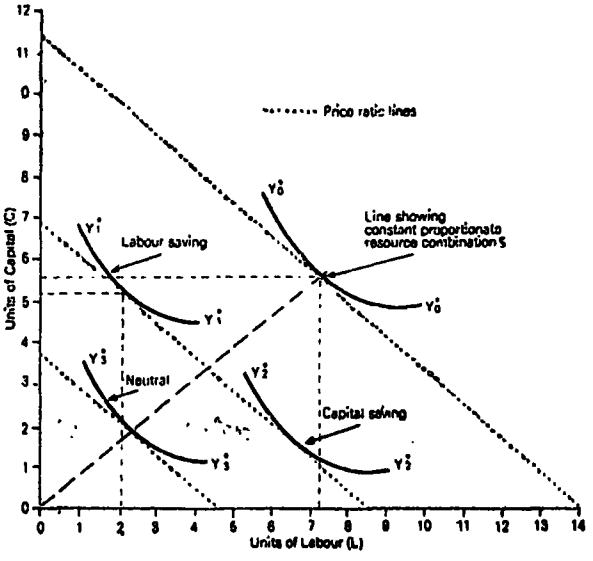

Fig. 2. Changes in Technology

At this constant price ratio the movement from $Y_0{}^*Y_0{}^*$ to $Y_1{}^*Y_1{}^*$ dictates a new economically optimum resource combination for producing the given output (Fig. 2). This combination requires much less labour (2·00 units instead of 7·25 units), but almost as much capital (5·25 units instead of 5·50 units). Blaug (1963) has suggested that innovations which cause such a change at a constant price ratio be classified as 'labour-saving'. Similarly, innovations which cause a movement like that from $Y_0{}^*Y_0{}^*$ to $Y_2{}^*Y_2{}^*$ are classified as 'capital-saving'. The movement to $Y_3{}^*Y_3{}^*$, on the other hand, does not involve any alteration in the optimum proportionate resource combination, and is accordingly classified as 'neutral'. These classifications of Blaug are adopted in the present paper.

In practice, of course, technological changes do not usually involve such marked shifts in position as those in Fig. 2 : labour and capital-saving innovations more commonly cause lesser movements, like those to $Y_4{}^*Y_4{}^*$ and $Y_5{}^*Y_5{}^*$ of Fig. 3.

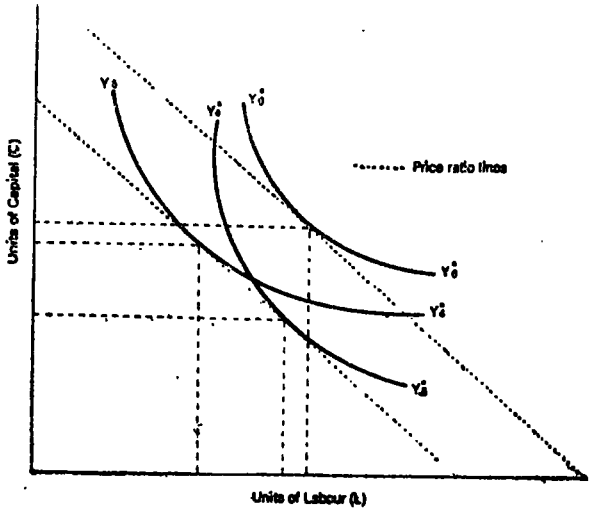

Fig. 3. Labour-saving and Capital-saving Changes.

In practice, too, the situation at issue is normally much more complex and much more difficult to analyse, notably owing to the reasons that more inputs are involved, that reliable data on the positions of the isoquants is not obtainable, that prices and yields per unit are not constant but variable, and that technological change tends to be continuing rather than occurring in discrete 'jumps'.

It is nonetheless believed that the basic principles just outlined help to explain the second major argument of the present paper : this is that the new technologies being developed by rubber research institutes, and the technological changes which are thereby encouraged, often tend to stress labour-saving rather than capital-saving adjustments. In the current social and economic situation of the main rubber-producing countries, however, capital-saving adjustments, and techniques which use greater rather than lesser inputs of labour, are generally much more appropriate. The nature of research and recommendations from these rubber institutes is therefore felt to be causing some undesirable long term social and economic changes in the national economies concerned. Much more comprehensive treatments of the economics of techniques and technologies have been presented by Sen (1968), Kennedy & Thirlwall (1972), and Yotopoulos & Nugent (1976).

Major Arguments

The two major arguments of this paper are :—

(1) That in respect of techniques within particular technologies, the research undertaken and recommendations made do not always concentrate sufficiently on that section of the isoquant indicated as optimum by input price

ratios ; in doing this the research and recommendations also tend to be biased towards an undue usage of capital at the expense of labour inputs, and are thus felt to have influenced actual resource allocations in this direction. In reference to the isoquant of Fig. 1, for example, research and recommendations may concentrate erroneously on establishing better the technique in position A, rather than that in position B.

(2) That in respect of new technologies, the research undertaken puts undue emphasis on labour-saving innovations, and thus tends to encourage capital-labour combinations in rubber production which are not desirable in a national context.

To be more specific, it is argued here that many rubber-producing techniques and technologies are inappropriate, in the sense of (1) and (2) above, to the situation of the smallholding rubber farms ; these are the farms which typically involve 2 - 3 ha of rubber, and which together form by far the largest proportion of the international planted area of *Hevea* (Table 1). On such farms the effective or ' opportunity ' cost of labour is usually much lower per unit than that in the large farm sector ; this is especially so where family labour is involved. Capital costs, on the other hand, are usually more expensive per unit, owing to considerable dis-economies of scale in their usage. Whilst the generation of rubber-producing techniques and technologies has certainly improved the earlier economic situation of many rubber smallholdings, it is considered that the advances made would have been much larger had the research and development emphases been altered appropriately.

TABLE 1 : RUBBER AREAS UNDER SMALLHOLDINGS AND ESTATES, 1965 — 74 ('000 HECTARES)

Territory	Year	Smallholdings	Estates	Total
Indonesia	1973	1,863·3	455·1	2,318·4
Peninsular Malaysia	1973	1,104·6	589·4	1,694·0
Thailand	1974	1,400·0	—	1,400·0
East Malaysia	1973	256·3	32·1	288·4
Nigeria	1965	207·5	31·9	239·4
Sri Lanka	1973	121·0	107·5	228·5
India	1974	164·0	57·3	221·3
Other Africa	a	74·2	188·1	262·3
Remaining Countries	a	74·6	209·2	283·8
TOTALS[b]		5,265·5	1,670·6	6,936·1

Sources : (of data on Indonesia) : Balai Penelitian Perkebunan Bogor (1975)
(of data on Malaysia) : Malaysia. Department of Statistics (1975)
(of data on Thailand) : Panyalakshana & Blencowe (1975)
(of data on other countries) : International Rubber Study Group (1976)

Notes : (a) For a range of years in the 1960s and 1970s
(b) Refer to the different years shown.

It must also be added, however, that the techniques and technologies in question have usually been very appropriate to the estates, which typically plant around 500 hectares of rubber. Under these circumstances all labour is hired, and is generally much more costly than on smallholdings. Indeed the work in this regard has contributed outstandingly to the economics of rubber estate management, and reflects huge credit on all those concerned in the many years of painstaking research which were involved.

The arguments of this paper implicitly assume a major role for the publicly financed research institutes as agents of change in the rubber industry. There are, of course, other agents at work, notably in the direct effects of relative prices of inputs in influencing the techniques chosen by farmers, in the actions of leading farmers (in response to the same relative prices) in developing new agricultural technologies, and in the results of research undertaken by professional employees of the large estate companies. Yet the latter influence at least will again reinforce the emphasis on techniques and technologies appropriate for estate conditions. On balance, it is felt by these authors that the adverse socio-economic position of most rubber smallholders, and especially their lack of ability to experiment on their own account, often makes the influence of the publicly financed institutes a significant one in respect of economic improvement; this is especially so where publicly financed development programmes are concerned. It is also likely to be more important in Peninsular Malaysia and Sri Lanka than in other countries where communications are not so good.

EMPHASES IN PAST RESEARCH

The Colonial Period

Two periods can be clearly distinguished in the past history of international rubber research; the 'colonial period' from the beginnings of the rubber industry until the 1950s, and the 'recent period' since then. During the colonial period the research and development policies of all major rubber-producing countries except Thailand were variously determined by the British and Dutch imperial governments, and by the generally similar attitudes which characterized this stage of political history.

The dominant policy of the research institutes during the colonial period was to develop techniques which supported the economic improvement of rubber estate agriculture. This could be partly ascribed to a belief in the inherent superiority of estate-oriented 'scientific' agriculture over the homespun methods of local peasants. Probably the more significant justification, however, was a political philosophy of strong assistance for an estate industry largely financed by capital from the metropolitan power. Especially over the first twenty to thirty years of the industry almost the only interest in rubber smallholdings by each institute was a concern over preventing diseases which might spread from them to the estates.

Somewhat paradoxically, and amusingly in retrospect, the techniques of scientific husbandry supported by the institutes and adopted by estates did not always prove so desirable. This was true in Peninsular Malaysia of the 'clean weeding' of estates which was recommended by the Department of Agriculture, and later by the Rubber Research Institute of Malaya (RRIM) after its establishment in 1928. This technique, which was supposed to maximize the supply of nutrients to the plant and to prevent the spread of disease, actually had diametrically opposite effects, and seriously reduced the productivity of vast areas; it was probably the main explanation of the lower average yields on estates than on smallholdings in years not covered by the output restriction schemes which unfairly penalized the smaller farmers (Table 2). These yields on both estates and smallholdings were almost entirely secured from unselected seedling material, which was overwhelmingly preponderant at that time.

In reaction to this experience, indeed, Anon (1932) then advocated for a few years the promotion of 'forestry' cultivation methods involving the establishment on rubber plantations of conditions similar to those in the jungle.

Apart from this unfortunate episode, however, many other innovations useful to estate agriculture were pioneered by the RRIM, especially in the selection and breeding of new clones and selected seedlings, and in the development of less intensive tapping systems under which such clones responded best. It should also be mentioned here that, following a special enquiry (Federated Malay States, 1933), a 'Smallholders Advisory Service' was organized by the RRIM. This very small Service was mainly preoccupied with 'teaching' smallholders methods of cultivation suitable to estates, however, and did little to take account of the real economic situation and problems of the farmers concerned. In the 1940s little economic progress was made in either the smallholding or estate sectors of the Malaysian industry, owing initially to the Japanese occupation and later to the Communist Emergency.

TABLE 2 : AVERAGE YIELDS ON ESTATES AND SMALLHOLDINGS, PENINSULAR MALAYSIA, 1929 — 40 (kg per mature ha)

Year	Average Yields[a]		
	Estates	Smallholdings	Overall
1929	459	567	503
1930	424	562	480
1931	416	497	449
1932	408	434	419
1933	394	519	445
1934	358	443	393
1935	327	287	311
1936	306	269	291
1937	318	368	298
1938	322	226	284
1939	323	218	279
1940	463	426	448

Sources (of output) : Malaysia. Department of Statistics (1932 — 75).

(of mature areas) : Bauer (1948).

Note : a. Average smallholding yields dropped suddenly below average estate yields in 1935, following implementation of the International Rubber Restriction Scheme in late 1934. The administrative discrimination behind this drastic change in yield relationships has been thoroughly analysed by both Bauer (1948) and Lim (1971).

In Indonesia during the colonial period, the neglect of smallholdings was even more complete than in Peninsular Malaysia. On the other hand the various institutes administered by the Association of Central Experiment Stations (or CPV) made major and internationally pre-eminent contributions to the progress of estate agriculture ; one early landmark was the development by van Helten, at Bogor in 1916, of the first rubber clone. The research in Indonesia up to 1940 has been

thoroughly discussed by Dijkman (1951). The 1940s and the 1950s in Indonesia were periods of little progress, owing first to the Japanese invasion, and subsequently to the war of independence with Holland.

The Recent Period

In the era of political independence, large changes in the governmental attitude to smallholders have undoubtedly occurred in all the main rubber-producing countries. These changes of attitude have also made themselves felt, to a varying extent, at the level of research and development work in the publicly financed institutes. It is pertinent to note, however, that the change has primarily been one in political philosophy, in the sense that 'smallholdings' are now regarded as legitimate and important objects of attention ; the original preference for scientific agriculture in an estate context still remains to a considerable extent, and is felt to explain a continuing misapplication of estate-oriented techniques and technologies to the problems of smallholdings. This misapplication is particularly severe in respect of the very small farms of two or less hectares : here lower-cost family labour is normally predominent, and resources to purchase capital inputs of any kind almost non-existent.

The most progress in re-orienting rubber research and development towards the needs of smallholders has undoubtedly been made in Peninsular Malaysia. It was there that the changed political attitudes of government were most speedily reflected in public policies, first in the ambitious smallholding (and estate) replanting schemes which began in 1953, and later in the new planting schemes promoted by the Federal Land Development Authority and other bodies ; these schemes first had substantial impact in the early sixties. From the late 1950s, too, the Smallholders' Advisory Service of the RRIM began a major expansion which had made it a considerable influence at village level by 1965 ; this work has been vigorously continued in the 1970s by the Rubber Industry Smallholders' Development Authority.

At the level of rubber research in Peninsular Malaysia, the change in attitude took somewhat longer to occur. Extensive surveys of conditions in the production and processing of smallholders' rubber were commenced by research workers in the mid-1960s, however, and the information collected in these surveys had become a significant consideration to those concerned with applied problems by the early 1970s. This has been reflected in the attention given to smallholders' problems in most applied production and processing studies of the RRIM. Some indication of the altered emphasis is given by recent editions of the Planters' Bulletin, Anon (1970 — 76). It is nonetheless evident that such work is mainly geared to the problems of the larger better endowed rubber smallholders, for whom relatively capital intensive techniques and technologies are anyhow more appropriate.

In Sri Lanka, too, the attention to smallholder problems began early in the era of Independence, and has been quite substantial, though with a similar bias to that in Malaysia. In Thailand, where there is virtually no estate sector, relatively little research of any kind was done until the establishment of the Rubber Research Center at Hatyai in the mid-1960s. Since then, however, the exclusive preoccupation of the Center with smallholding problems has produced impressive results, both in research and in the active improvement work which has started over a wide area of the rubber smallholding industry.

In Indonesia the change in orientation to smallholders' problems took longer than elsewhere, and significant advances in this respect only began in the 1970s. A preoccupation with furthering economic progress in the estate sector can be quite clearly distinguished from one of the major publications of the Balai Penelitian Perkebunan Bogor (BPPB), the *Menara Perkebunan* (1970 — 76). In Indonesia too,

however, an enhanced awareness of smallholders' problems is quite evident, notably in the recent proposals of the BPPB (1974) for a research station which concentrates solely on studies of smallholding rubber. This station, at Sembawa near Palembang in South Sumatra Province, is now being actively developed.

SPECIFIC EXAMPLES OF BIAS

Tapping System

A good example of bias, in the sense of the first major argument above, is given by the research work on tapping systems. With few exceptions the main focus of this work has been to move towards a greater usage of capital at the expense of labour inputs (Fig. 1). In this particular instance the capital inputs comprise stimulants, fertilisers, and trees (whose rate of usage can be measured by their rate of bark consumption). Though varying somewhat with the particular clones and circumstances, the commonest official recommendation by research institutes in all countries is for S/2, d/2, 100% tapping, accompanied by adequate maintenance. Where stimulants are also available S/2, d/3, 75% or S/2, d/4, 50% tapping, both in conjunction with stimulants, are frequently advocated.

There is no doubt that the bias towards greater capital inputs represented by these systems is appropriate to the economic position of the estates. It does not suit the position of most smallholdings, however. Field surveys of small rubber farms have universally shown that their commonest tapping system is a half spiral cut applied on as many days a month as tapping is feasible. Thus a careful survey of 495 high-yielding smallholdings of 2 - 3 ha in Peninsular Malaysia in 1964 denoted that most holdings were tapped on an S/2 system on well over 15 days a month (Table 3). A similar practice of tapping frequencies higher than alternate daily (subject to the much higher rainfall) was observed by Barlow *et al.* (1976) in a survey of 280 smallholdings in Sri Lanka, and by the Balai Penelitian Perkebunan Bogor (1976) in an extensive survey of 500 rubber smallholdings still being continued in the province of South Sumatra.

TABLE 3 : TAPPING FREQUENCIES AND YIELDS ON HIGH-YIELDING SMALLHOLDINGS, PENINSULAR MALAYSIA, 1964

	Days Tapping per Month				
	Below 10	10 – 14	15 – 19	20 – 24	25 and over
No. of holdings	22	105	164	158	46
Average yields (kg latex[a] per ha)	680	841	984	1,163	1,234

Source : Rubber Research Institute of Malaya (1964). Data referred to 495 holdings which were almost all on half-spiral tapping.

Note : (a) Yields of lower grades are *not* included.

It should be noted that most of the farms covered by these field surveys were operated by better-than-average small farmers, whose capital resources were relatively larger than those of the majority of other farmers in their areas. These other farmers would have even greater reason to tap intensively. It thus appears that in most circumstances farmers had ignored the typical recommendations of their local advisory services that there should be strict adherence to half spiral alternate daily tapping. That the farmers observed in Malaysia had ample economic justification

for their, actions in a situation of low effective labour costs, is indicated by the higher average yields they secured from more tapping days (Table 3).

Yet despite this evidence of actual practices on rubber smallholdings, little attempt has yet been made at any research institute to explore the feasibility of more labour-intensive resource combinations. As suggested earlier, most acknowledgement of the smallholders' position has been made by the RRIM, which in its 'environmax' planting recommendations (Anon, 1975a), for example, specifically recognises that clones selected for conditions on individual smallholdings should be 'tolerant of high-frequency tapping'. Despite this, however, little work appears to have been undertaken by the RRIM to investigate the response of important clones to tapping systems more frequent than alternate daily. The prime concentration by the RRIM in respect of smallholders' tapping appears to have been on extensive trials with yield stimulants. In these trials, which involved three rounds of Ethrel stimulant in conjunction with S/2, d/2, 100% tapping, excellent responses were obtained from 30% of the sample of 2,623 rubber holdings involved ; these all gave an annual response rate greater than 670 kg per ha (Abraham & Manikam, 1973). The holdings concerned, however, were well-maintained farms previously tapped on the S/2, d/2, 100% system, and could not be considered typical of the average smallholding in the Peninsular Malaysian context. It is pertinent to note also that a further 2,000 odd smallholders had withdrawn from the original project, partly because of poor responses to the first and second rounds of stimulation. These poor responses were mainly attributed to the previous dominance of intensive daily tapping systems after which little or no response to stimulant could be expected, to poor fertility, and to unsuitable planting materials. No research at all on the labour-intensive tapping systems appropriate to smallholdings appears to have been done by research institutes in any of the other rubber producing countries.

A more basic problem underlying the generation of labour-capital resource combinations more suitable to the tapping of smallholdings is the historic emphasis on the selection of improved planting materials which respond well to S/2, d/2, 100% tapping under estate conditions. This aspect brings in the second major argument of this paper in that it involves the basic nature of the innovation concerned. Since the S/2, d/2, 100% system has always been treated as the standard system in breeding work, and since all large scale clone (and seedling) trials have always been carried out on estates where such systems have been predominant, it is natural that this system has usually proved to be the best in subsequent comparisons of different tapping systems. The normal finding that most available planting materials respond poorly to half spiral tapping more intensive than alternate daily is a direct result of the exclusion during selection of materials which might respond well under these circumstances. Essentially, therefore, the development has been one of inherently labour-saving innovations (in the form of the planting materials now available) which adapt badly to labour-intensive treatment. The basic technology made available through these materials is therefore inappropriate to the most common tapping conditions of the smallholding industry. This labour-saving bias in current planting material is likely to be reinforced further, now that additional selection criteria have been introduced in the form of shorter cuts and lower frequency tapping systems in conjunction with yield stimulation (see, for example, Anon, 1975b).

Planting Methods

Further important biases in techniques and technologies may be detected in the research work on planting methods. In a broad economic perspective towards both estates and smallholdings, it is generally desirable to develop planting methods which reduce the period of immaturity and which increase the yield of the trees during subsequent exploitation. Reduced immaturity, and the better rate of growth which underlies it, bring the flow of net revenue nearer the present and thus enhance

the profitability of a planting (Etherington & Jayasuriya, 1976). Accepting these general goals, however, it is again economically advantageous, in the situation of smallholdings, to focus on relatively labour-intensive combinations of resources.

Planting density: In the choice of tree planting density it is considered that the official recommendations of most research institutes indicate a technique (within the existing technology of planting) which is often inappropriate to the input price-ratios faced by most rubber smallholders. Since labour and trees are directly complementary on a given tapping system, it is more helpful here to consider a fixed ratio input of tapping labour and trees on the horizontal axis of a model like that of Fig. 1 : other capital, which comprises all the non-tree capital inputs in planting (including various equipment and material inputs), is measured on the vertical axis. The yield isoquant will be of the same form as Y*Y* in Fig. 1. Whilst the common official recommendation for both estates and smallholdings is for plantings which secure around 300 trees per ha in tapping (combined with non-tree capital inputs of fertiliser and other material resources), smallholders in all countries normally plant so as to obtain from 400 to 600 tapped trees combined with lesser quantities of other capital inputs. Thus tapped stands at these densities are common on improved smallholdings in South Sumatra (Balai Penelitian Perkebunan Bogor, 1976), but inputs of fertiliser and other material resources are either negligible or entirely absent. It is pertinent to note here that Barlow & Lim (1967), in an assessment based on the single comprehensive planting density experiment for which results were available over many years of tapping, found that under smallholding conditions economically optimum tapping densities were often higher than 300 trees per hectare. The increases in yield obtained at higher densities than this meant that from 500 — 600 trees per hectare were optimum where the opportunity cost of labour was low, or when the trees were tapped on a crop sharing system.

As in the case of tapping system assessments, little serious attempt appears to have been made by any major research institute to explore the merits of planting densities much greater than those currently recommended.

Intercropping: The lack of experimentation on intercropping constitutes a major bias in development of new technologies relevant to smallholding agriculture. Intercropping is rarely of economic importance to estates, since it is much too labour-intensive, but it can be of major importance to most smallholders. In countries like Peninsular Malaysia and Sri Lanka where there is a shortage of land it offers an alternative source of income during the immature period. In South Sumatra and Kalimantan, where land is not scarce, the 'intercrop' of padi and other plants is an essential source of subsistence which often justifies the parallel planting of rubber trees. Yet despite this crucial position of intercrops in the rubber planting cycles or Indonesia, relatively little research appears to have been directed towards their improvement (Jusnidar Amri, 1970). In Peninsular Malaysia, however the increasing work in this respect in the seventies has already produced very useful advances (Anon, 1973).

Weeding: The lack of experimentation on manual weeding methods, and the absence of much guidance in this respect to smallholders, is yet another bias in the development of technique, where until now the emphasis has been on chemical control. Again in reference to the vast areas of overgrown smallholdings in Kalimantan and Sumatra, it is considered that the development of more suitable manual weed control techniques would have major economic benefits: this would be expressed both in the reduction of the period of immaturity, which now lasts from 10 — 15 years, and in an increase in the productivity of the areas brought into tapping.

Nurseries : In one area of planting methods, that of nursery and propagation approaches, the range of advanced techniques developed by research workers seem generally appropriate to the situation of both estates and smallholdings. Thus the methods of producing budded stumps in central nurseries, and of field budding on to seed at stake, are particularly relevant to the situation of the smallholders.

Even here, however, there is some discrimination against the smallholders in the sense that nurseries with budwood, or knowledge of field budding techniques, are often not made available to the farmers concerned. Thus, although in Thailand field budding is being actively taught to smallholders by the extension services (Phit Panyalakshana *et al.*, 1975) and is becoming a major and successful means of establishing improved planting materials, the only other country where this occurs so to some extent is Peninsular Malaysia. The implementation of this technique is apparently being ignored in other rubber producing countries. It should also be recognized, however, that the reason for this difference in extension practice lies to some extent in differences in overall agricultural development policies. These are to be discussed in a further paper.

Processing

The range of new processing technologies developed by research institutes can, like nursery and propagation techniques, be made quite appropriate to the situation of smallholdings. Whilst the technology of block rubber manufacture, which is most relevant to the smallholding situation, is inherently capital-intensive with substantial economies of scale, there are good ways in which it can be adapted to the position of the small rubber farmer. This has been outstandingly demonstrated, for example, by the work of the Malaysian Rubber Development Corporation in its network of collection stations and central factories which serve rubber smallholders in Peninsular Malaysia (Rosli Kassim, 1976). It has also been shown in the work of group processing centres for rubber sheet making in Sri Lanka and Malaysia (Dissanayake, 1975), and of the Group Marketing Organisations in Thailand (Sribo Chaiprasit & Lim, 1975). There has, in addition, been substantial adaptive work, such as that of Achmad Soedarsan dan Sutrisno Budiman (1970) and of Chambe (1972), whereby existing techniques are better tailored to the needs of the smallholders concerned. An overall review of how technological innovations in processing have been adapted to smallholder requirements has been made by Voon (1976). There is little doubt that room exists for much further emphasis in this respect.

The Experimental Regime

One basic problem in the generation of techniques and technologies more appropriate to the position of smallholders lies in the traditional experimental regime on research stations. This aspect has already been touched on above in relation to tapping systems. So far as rubber cropping investigations are concerned, this traditional regime normally involves a planting density sufficient to obtain 300 trees per hectare in tapping, the planting of covers and the use of ample fertiliser and weedicides during immaturity, and the employment of S/2, d/2, 100% tapping and a further application of material inputs during maturity. Where these conditions are regarded as the norm, the initiation of experiments better geared to the needs of smallholders in the sense described above is not easy. Thus experiments involving intensive tapping of high density stands to which little fertiliser has been applied are virtually impossible on any rubber experimentatation now in existence, since the facilities for such an experiment are just not available unless complete new planting is undertaken. Yet it is crucial in experimentation geared to the needs of smallholders to adopt regimes which are more nearly parallel to the conditions on these

farms, and to study the interaction between major variables in this context. This whole problem has been discussed, in relation to the new smallholding experiment station of the Balai Penelitian Perkebunan Bogor at Sembawa, by Barlow (1975).

CONCLUSION

This paper has attempted to highlight some major issues in rubber research which it is felt deserve wide discussion and examination. It is considered that a better adaptation of techniques and technologies to the situation of smallholders can produce substantial economic benefits, both to individual smallholders and to the national economies in which these smallholders are situated.

It is also considered that past biases in rubber research have had major effects on overall agricultural development policies in the rubber-producing countries. These biases have influenced policies very heavily in favour of relatively capital-intensive measures, which tend to benefit relatively few people at the expense of the majority who receive virtually no economic assistance.

The economic benefits from changed emphases in research, and the influence of existing techniques and technologies on policies of agricultural development, will be considered in a further paper.

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