The Contribution of Research to the Economic Development of the Rubber Industry in Sri Lanka

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The Rubber Research Institute of Sri Lanka (RRISL) is situated at Agalawatta, approximately 50 miles from Colombo, in the Kalutara District, one of the largest rubber growing districts in Sri Lanka.
The work of the Institute can be conveniently divided into three main sections: biological research, chemical research and extension. In biological research, the scientists concerned try to improve the yield of the rubber tree by various methods, such as breeding new high yielding disease-resistant rubber trees, which will grow in the different soils and climatic zones where rubber is grown in our country. Improving the cultural practices, eg. developing better nursery management systems, breeding methods, tapping systems, soil and water conservation methods, improved yield stimulants, inter-row management and collection and transport of latex, also come under the purview of the biological scientist.
The chemist on the other hand is concerned with the improvement of the product, either the raw rubber, in which case he is a rubber chemist or the finished goods where he would be a rubber technologist.
The extension personnel are responsible for the rapid transfer of the new methods developed by the scientists to the rubber growers, both on the large estates and in smallholdings.

The recent developments established by the RRISL and some of the ongoing research work of the Institute will be described in this paper.

BIOLOGICAL RESEARCH

Plant Breeding

The Genetics and Plant Breeding Department of the Institute has developed several new high yielding clones by the method of hand pollination. Rubber (*Hevea brasiliensis*) flowers are normally pollinated by insects, but then the crosses are not controlled and the progeny are variable. Selected crosses between high yielding clones, with other desirable characters, such as resistance to diseases and wind damage, rapid bark renewal, good branching habits and ability to grow under various soil and climatic conditions, can be made by protecting the female flowers from natural pollination and transferring the pollen of selected clones on to the stigma of such flowers. The progeny of these selected crosses has a much higher probability of combining the essential character of high yield with other desirable characters than the crosses left purely to chance, as happens in nature with insect pollination.

The Institute has developed the RRIC 100 series clones in this manner and recommended the planting of RRIC 100, 102, 103, 104 and 105 recently.
The main contribution in new clones in the last two years was the discovery of the South American Leaf Blight (SALB) resistant clones RRIC 121, RRIC 130 and 72 — 133. The yields of both RRIC 121 and RRIC 130 are very high and the growth of RRIC 121 is above average.

SALB is the most devastating disease of the rubber tree known anywhere in the world. At present it is confined to the South American region, the original home of *Hevea;* but there is no guarantee that this dreaded disease will not spread to the South East Asian rubber growing areas in the future, with the fast air traffic now linking various parts of the world. Although Hevea originated in Brazil and other South American countries, they have not been able to grow the crop on a commercial scale, entirely because of its susceptibility to SALB in those countries. Therefore, the value of the development of a SALB resistant, high yielding clone in Sri Lanka is a significant contribution to the industry, by our scientists.

Tapping Systems

The normal daily task of a tapper in Sri Lanka is about 250 trees, whereas the Malaysian tapper does up to 750 trees per day. Tapping and collection account for about 33 per cent of the cost of production of rubber. Therefore, any improvement in tapping systems can result in significant savings for the industry. The RRISL is studying methods of puncture tapping with yield stimulants, where vertical grooves made on the rubber tree are first treated with a yield stimulant and latex is extracted by piercing the bark at 2 to 3 points with a pointed instrument, rather than by the conventional method of shaving the bark with a tapping knife. These experiments are in their initial stages and indicate that the task size can be significantly increased by this method, while keeping the yields constant. However, further studies are necessary and an economic evaluation must be carried out before coming to any conclusions.

Yield Stimulants

These are materials that, when applied on the scraped bark of the rubber tree, either immediately above or below the tapping cut or on the cut itself, increase the yield of latex quite significantly. We have found that a material called Ethrel, which when applied to the tree releases ethylene, is the best yield stimulant available for rubber up to date. However, early studies showed that although Ethrel can increase the yield of latex by 100 per cent on first application, yields fell off gradually and, if the stimulant is used frequently, the yield can fall below that of control trees, which are untreated. This leads to further research, and it has now been established that Ethrel will give best results if used at low concentration 3 to 4 times per year. We are currently recommending the application of Ethrel at 5% concentration, on the tapping cut immediately after the South West Monsoon rains and twice thereafter. This has resulted in a steady yield increase of 15% to 25%, and there has been no adverse effects over several years.

Intercropping

Intercropping is an innovation recently introduced by the RRISL, which should be most attractive to smallholders; as it would give them an income in the first few years after replanting. Intercropping can be done for only about 4 years, from the time of replanting until the leaf canopy closes over. Very few plant will grow under the dense shade provided by mature rubber trees, planted on the normal spacing for rubber.

Intercropping rubber planted at spacings of 2.5 m X 9.0 m with crops such as bananas, passion fruit, pineapples, cocoa and coffee has provided a good income and has had no adverse effects on the growth of rubber, when carried out according to the Institute's recommendations. Further experiments have to be carried out to establish whether coffee can be grown under mature rubber to yield an economic return.

One of the problems with intercropped pineapples is that of weed control. We have found that Diuron, a pre-emergent herbicide can be used successfully for weed control in this crop. Further studies are being carried out on this subject, as pineapple growing provides very attractive returns.

Various grasses have been grown with rubber to find out whether we can suggest a suitable farming system to the smallholder, where he can grow animals on his land. *Panicum* species have produced more dry matter than *Brachiaria* species tested both when grown alone or in combination with a legume. *B. brizantha* and *P. maximum* depressed growth of *Hevea* significantly when grown above or in combination with a legume when compared with *Pueraria* or natural covers. In terms of both dry matter and availability of nitrogen, a mixed pasture of grass and legumes appears to be best under our conditions.

Tissue culture

We have made considerable progress in tissue culture, having perfected methods of inducing root growth in callus cultures, and produced shoot growth at least on one occasion. Root differentiation was observed when *Hevea* calluses grown on a high auxin medium was transferred to low auxin media with kinetin. Low levels of cinnamic acid in the presence of kinetin also induce root differentiation. We are now developing a method that can be repeated for the production of shoots, and from there the production of plantlets would be relatively easy.

Disease control

There are five major diseases, caused by fungi, affecting the rubber tree in Sri Lanka. Three of these are leaf (*Oidium* and *Phytophthora*) and panel diseases (*Phytophthora*) and the other two root diseases (*Rigidoporus* and *Xylaria*). The RRISL has found that the majority of clones recommended for planting by the Institute at present are tolerant to *Oidium* leaf disease, so that control measures against it are not warranted in the wet low country districts, where rubber is grown. We have also found that the weather patterns in Sri Lanka are such that *Phytophthora* leaf disease does not occur on an epidemic scale regularly in this country, and according to our advice, no control measures are taken against this disease, too. *Phytophthora* infection of the bark, leading to Black Stripe or Bark Rot, occurs in exceptionally wet years, and control measures against it, as developed by the RRISL, are well known and adopted where necessary by estates. Therefore, the major disease problems on rubber are those caused by root infecting fungi.

We have studied the biology of the causal fungi and introduced several innovations in the control of the diseases caused by them. The size of the food base is important in the initiation and spread of both diseases. Only a few plants were infected, however, when quite large food bases were buried near plants; but even small pieces of inoculum caused infection when placed in contact with roots. Therefore, soil conditions, environment and placement of the inoculum are all closely linked with the spread of the diseases, and infected material has been found to be viable for more than 30 months in the soil. The introduction of sulphur to the soil, lowers its pH and helps in the suppression of the pathogen and encourages the growth of certain fungi antagonistic to it. Studies are now being carried out to use all this information to develop a method of biological control of these root diseases.

Soils and fertilizers

One of our main interests in the Soils and Plant Nutrition Department of the Institute is to study the response of the rubber tree to the supply of nutrients. We have shown that yield increases in the range of 5 to 32 per cent can be achieved by the proper fertilization of rubber trees. The requirements of various elements by different clones can be distinct, and differ according to the type of soil on which the crop is grown. Therefore, special fertilizer mixtures are recommended by us according to clone and soil type generally. This has been developed further, and the Institute now carries out soil and foliar analyses to recommend special fertilizers to different fields on each estate, according to the requirements of each area. Therefore, in certain cases, we may recommend the use of only one or two fertilizer elements, instead of the general fertilizer mixtures hitherto applied. The savings effected by this innovation are quite substantial.

Our studies have also shown that urea is as effective as sulphate of ammonia as a source of nitrogen for mature rubber, so that, with effect from 1981, the Institute has recommended the complete substitution of urea in place of ammonium sulphate for all mature rubber in Sri Lanka. Urea contains more nitrogen W/W, is cheaper than ammonium sulphate and is now manufactured in Sri Lanka, so that considerable economics will be effected by this substitution. Our studies have also shown that the local dolomite can replace imported Epsom salts and kieserite as a source of magnesium for rubber replantings. This has again resulted in significant savings in the fertilizer bills of rubber growers.

We have shown that certain cover management practices such as the establishment of legumes and fertilizing them with phosphate will give long term beneficial effects on growth and yield of mature rubber. Investigations in soil conservation methods have shown that, a good mulch should be maintained over the ground until a legume cover is established in replanted areas. The ground should never be left bare or clean weeded until the legumes have grown.

RUBBER CHEMISTRY AND TECHNOLOGY.

Rubber Chemistry

The Rubber Chemistry Department of the Institute carries out studies on: rubber chemistry, rubber technology, specifications for dry rubber, chemical analyses of rubber and water samples, crepe rubber development, biochemistry of latex and non-rubber resources such as rubber seed oil and rubber seed meal.

We have found

(*a*) that storage hardening of liquid rubber can be reduced by incorporating a radical quencher,

(*b*) several applications for low temperature curing systems — an interesting and useful application is in the rubberising of bullock cart wheels,

(*c*) that low temperature curing systems based on natural rubber (NR) can be used to safeguard the tea bush against desiccation and borer attack, by effective sealing of pruning cuts,

(*d*) promising ebonite formulations for compression moulding of engineering components,

(*e*) a simple method of producing cyclised rubber — about 5 tons of this material is now manufactured every month in four estate factories, and replaces imported high styrene resins in various industrial processes eg. paints,

(*f*) that deproteinised NR prepared by papain/acid coagulation is satisfactory for cyclisation in the open mill using toluene sulphuric acid,

(*g*) that metal salts of higher fatty acids such as calcium stearate and the calcium salt of rubber seed oil fatty acid are very effective activities of sulphur vulcanization,

(*h*) that carboxy methyl cellulose can be used as a wetting agent in the manufacture of NR/carbon black masterbatch at the latex stage. The sheet form is the most suitable way to prepare the masterbatch for drying. Compounds made from this masterbatch have been tested out and found to be satisfactory,

(*i*) our studies leading to the development of a network bound antioxidant for NR have come to a temporary standstill due to the non-availability of the necessary chemical in commercial quantities, for exploitation of the process. Negotiations are now going on with a chemical manufacturing firm in the UK to remedy this situation.

We are studying the possibilities of:

(*a*) introducing thermoplastic properties to NR, by both grafting and blending techniques,

(*b*) synthesising amine-based antioxidants and dual purpose accelerators.

Rubber technology

One of the main functions of the technology section is to give an adequate technical service to the rubber products manufacturing industry, especially with regard to quality control of locally manufactured rubber goods. In the processing of latex, we have made significant contributions in the methods of preservation, concentration and dialysis of NR latex.

The use of solar energy for drying crepe rubber is quite appropriate in the context of the energy crisis. Our own studies are being supplemented by factory scale trials at Padukka Estate, where a solar collector unit has been installed for a new drying tower.

An useful non-rubber resource is rubber seed oil (RSO) of the triglycerides available in Sri Lanka. RSO is the only one which has useful drying properties. Light coloured alkyd resins have been prepared by us in a purified form and this has distinct possibilities of further development. However, the free import of linseed oil may hinder the rapid development of this industry. It is important for the Government to give the necessary impetus to such useful industries, by suitable import restrictions.

EXTENSION SERVICES

Advice to Smallholders

The Advisory Services Department has officers resident in many of the larger villages where rubber is the main source of income of the residents. These officers visit rubber smallholders and assist them in lining and holing their land in preparation for replanting, and continue the visits at regular intervals thereafter to provide advice on all aspects of rubber planting and aftercare such as: soil conservation, fertilization, disease control, tapping, collection and processing of rubber. No charge is levied for this service, and it is an entirely voluntary service provided by the Institute.

A project was started in 1980, with World Bank financing, to replant 45,000 acres of rubber land in the Kalutara, Ratnapura and Kegalla Districts during the period 1980 to 1984. The RRISL is playing a vital role in this project.

Improvement of Smallholder's rubber

The Institute started a scheme in 1973 to improve the quality of the sheet rubber produced by smallholders. This scheme is supported by the Government, which provides the financial assistance for it. The scheme consists in grouping smallholders together, to bring their latex to group Processing Centres (GPC), where processing facilities and a smokehouse is constructed with Government funds: each GPC being provided with grants and loans totalling Rs. 30,000/-. The present census of GPCs is as follows:

GPCs in operation	...	103
GPCs under construction	...	04
Total	...	107

One-day seminars are organised at regular intervals for officials operating GPCs, a set of account books necessary for the proper maintenance of accounts are provided, and every effort is made by our field staff to make these viable, self financing units.

The GPCs have had a significant effect on the quality of sheet rubber produced by smallholders, and it has been shown that these centres can produce up to 96 per cent of No. 1 smoked sheet, whereas the normal average of small-holders is about 15 per cent, No. 1 sheet, a major part of their product falling into Nos. 3, 4 and 5. This shows the impact that proper advice can have on rubber production in the villages.

CONCLUSION

The RRISL carries out research on the biology of the crop, with a view to increasing rubber yields; and in rubber chemistry and technology, so as to increase the value of the product.

Therefore, it is seen that the Institute carries out research essentially to increase the total income of the country from the rubber industry. The success of the enterprise in recent years, can be judged from a careful assessment of the contents of this paper.

Coconut Research — the Past, the Present, and the Future

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The Past

The dawn of the Twentieth Century saw Sri Lanka with a well developed plantation sector based on Tea, Rubber and Coconut. In the pioneering days, there was a useful participation of high officials of the Colonial Service in these enterprises. This factor would no doubt have contributed to the sizeable influence wielded then by plantation interests. There also lay one reason for the sharp dichotomy between the plantations and the indigenous farming community which persists to this day.

In sharp contrast with the unorganized subsistence level agriculture concerned with the provision of food and other produce for local needs, were the systematised and sophisticated arrangements of the export sector. The plantation interests, operating as they did on the basis of competitive efficiency, were not slow in recognizing the research needs of the young plantation industries. They had meanwhile formed themselves into Planter Associations, which had considerable voice and influence in the highest echelons of the Colonial Government. As a result of persistent agitation, Tea, Rubber and Coconut Research Institutes were set up in rapid succession during the 1920's. They took over the specialised function of research into the crops which had hitherto been the responsibility of the Department of Agriculture. The wisdom and vision behind these moves is reflected by the worldwide eminence that the three Research Institutes have each achieved.

A definite proposal for a Coconut Research Scheme was put forward in 1923 and resulted in the Coconut Research Ordinance No. 29 of 1928. The first meeting of the Board of Management took place on 27th April 1929. The finances were generated by a modest cess. The "Scheme" became the "Coconut Research Institute" in December 1950 with the passing of the Coconut Research Amendment Act No. 31 which simultaneously increased the cess.

Following the creation of a separate Ministry of Plantation Industries in 1970, the Coconut Development Act No. 46 of 1971 was promulgated. This created a co-ordinating body, the "Coconut Development Authority" with four separate Boards for Cultivation, Processing, Marketing and Research. Acting under Section 58 (i) of the Act, the Honourable Minister by Gazette notification of 30th March 1972 appointed the seven members to constitute the Coconut Research Board. This Board from then on took over the functions previously carried out by the Coconut Research Institute.

In October 1978, the Government established a Ministry for Coconut Industry, separate from the Ministry of Plantation Industries.

The Coconut Research Institute had its beginnings with just three technical divisions — Soil Chemistry, Chemistry and Genetics. Through progressive enlargement of its activities, the Institute grew to its present state with nine technical Divisions.

In 1951, the Coconut Research Board set up a separate Unit charged with the responsibility of improving the local breed of cattle. This developed into a Division of Agronomy in 1955 which included pasture and mixed-cropping responsibilities. A short time after, the Division was renamed the Agrostology Division and by 1973 had further expanded into two Divisions — Agrostology and Intercropping.

In 1953, the nucleus of the present division of Biometry was established with the appointment of a Technical Assistant (then styled the "Computor").

Initially, the responsibility for pest and disease research lay with a Crop Protection Unit attached to the Division of Botany. In 1955, a separate Crop Protection Division was formed.

From 1949 onwards, the Government commenced a Coconut Replanting Programme operated largely through an organization of Coconut Producers' co-operatives. As the Scheme gathered momentum in the mid-1950's, the responsibility shifted to a Planting Division at the Coconut Research Institute.

This Division still continues to discharge the function of producing seedlings for the use of the industry in its replanting programmes.

With the creation of the Coconut Cultivation Board in 1972, and the entrusting of extension and advisory functions to it, the Institute's own Advisory Division was transferred. This consisted of a number of Advisory Field officers and other supporting staff. This Division also maintained a spraying unit for pest and disease control.
The equipment, some staff and materials passed on to the Crop Protection Division.

The Chemistry Division which concentrated its early efforts towards the improvement of coconut based products was, from 1957 relieved of its obligations towards product technology research and obliged to confine its work to agronomic matters. This decision appears in retrospect to have been a retrograde one and a start has been made to recommence product research wherein clearly lie a number of rich rewards. The CRI now has a Division of Processing Research.

Until relatively recently, financial provisions for the Coconut Research Institute can only be described as niggardly. A meagre Government Grant of Rs. 30,000/- bolstered by a variable cess rarely exceeding Rs. 1,000,000. Today the Annual Budget works out at 15 to 20 million rupees and is steadily rising from year to year.
Virtually all of it is a Government Grant which provides the requisites of a Staff of about four hundred of whom about forty are at graduate level or above. The present allocation works out at about 1 to 2% of the export value of coconut products but at way below 1/2 to 10 of its gross national value.

The present

The Coconut Development Act No. 46 of 1971 defines the functions of the Coconut Research Board as follows:

(1) Conducting and furthering of scientific research in respect of the growth and cultivation of coconut palms, the growing of other crops and the engagement in animal husbandry on coconut plantations and the prevention and cure of diseases and pests.

(2) Establishment and maintenance of experimental stations and nurseries.

(3) Establishment and maintenance of pilot plants for the processing of coconut products and the fabrication of experimental processing equipment.

(4) Guiding and advising the coconut industry on all matters of a technical nature.

(5) The training of advisory and extension workers.

With the above objectives in view, the Institute conducts its research and services, through nine divisions whose broad functions towards increasing productivity through genetic and agronomic improvements and increased income from coconut lands, are currently as follows :—

(*a*) Agronomy — The study of pastures as an intercrop. Cattle improvement project. Other crops in association with coconut.

(*b*) Biometry with coconut statistics and Agricultural Economic, Statistical services, Crop forecasting, Agri-meteorology and Economics of coconut culture.

(*c*) Genetics and Propagation - Breeding and genetics of Coconut, Progeny testing, Nurseries and seedling behaviour.

(*d*) Plant biology — Physiology of the coconut palm, Tissue culture.

(*e*) Chemistry — Plant tissue analysis, Sap and carbonaceous products.

(*f*) Crop Protection — Managements of pests, diseases and weeds of coconut.

(*g*) Processing Research - Biochemistry, Microbiology and processing methods and finished products.

(*h*) Extention services — Publication

(*i*) Soils — Fertilizer behaviour, Soil surveys.

The technical Divisions are serviced by the necessary administrative, financial, engineering, transport, housing and library services.

The Institute conducts its activities at Bandirippuwa Estate, three sub-stations, two seed gardens, a progeny trial (all totalling about 1650 acres) and 12 nurseries (with a total seednut capacity of about 15 to 20 lakhs).

It is not possible to detail adequately and comprehensively, all of the major achievements of the Institute since its inception. It would suffice to say — and not immodest to claim — that the Institute has repaid amply the national investment so far made. The Institute has successfully established a firm foundation on which the industry can progress with confidence. Naturally, it would be foolhardy to claim that all the answers have been found for then the CRI would become an Institution with no claim for its continued existence.

In the field of selection and breeding, the basis of selection procedures has been established and criteria identified for recognising promising "mother palms". Much is known of the inheritance of material traits by progeny testing and useful "prepotent palms" have been found. Techniques of controlled pollination by proper collection, processing, storage and utilisation have been developed and imparted to the private sector as well. The Institute was one of the earliest to systematically study inter-varietal hybridisation and produced two valuable strains :—

"CRIC 60" — tall x tall. Late flowering and high yielding. Suited to all areas where coconut can be grown.

"CRIC 65". — tall x dwarf or dwarf x tall. Early flowering and high yielding but more critical in their requirements of soil and climate.

Other promising crosses are under test. Two seed-gardens for the commercial production of hybrid seed have been planted and one will within a few years, be in full production. Hybrid performance is being assessed under different agroclimatic conditions and with and without supplementary irrigation.

Studies on optimum planting distances and methods are being carried out.

A laboratory for attempts to produce plantlets by tissue culture techniques will be commissioned shortly, while some preliminary work has already been done.

Young seedlings in sand culture have been employed to demonstrate visual symptoms of individual nutrient deficiencies and to produce an inventory of use of the nutrient elements in the nut at planting.

Methods of foliar analysis have been intensively investigated, attempts made to establish critical levels, to relate nutrient contents to visual disorders, to compile balance sheets for nutrient uptake and utilization and to explore the validity of using nut water or inflorescence sap in analytical studies.

A series of studies are in hand to study the physiology of tapping trees for inflorescence sap, its biochemistry and fermentation characteristics, its potential utilisation for a number of traditional and unconventional products and microbiological studies of the successions in fermenting sap and the possibility of using isolated strains for consistent and improved quality of fermentation products and to improve the efficiency of the process.

Designs for improved Copra Kilns and drying and storage procedures and an improved "continuous generator" process for the production of vinegar have been released to the industry.

Utilization of by-products and uses for waste products are continuously under scrutiny. Use of coir dust as a mulch, trunks for timber uses or as a starting material for charcoal production, nut water, products from alkaline oxidation and distillation of coconut shell, collection of yeasts from toddy ferments, are some of the studies in progress.

Although the coconut palm in Sri Lanka is subject to attack by only a few fungal parasites, there are several important insect pests of the crop. Principal among them are the Coconut caterpillar (*Nephantis serinopa*), the Leaf Scale (*Aspidiotus destructor*), the Red Weevil (*Rhynqophorus ferrugineus*) and the Black beetle (*Oryctes rhinoceros*).

In addition there are several others which are of sporadic occurrence or less damaging.

Since 1958, when a pupal parasite named *Trichospilus pupivora* was first bred in captivity and released to control a severe outbreak of *Nephantis serinopa*, the accent and emphasis of the Divisions activities has been very strongly in the direction of biological control. This is desirable from the points of view of effectiveness, safety and economy.

Perhaps the most effective demonstration of this valuable technique was when a hitherto not experienced outbreak of the coconut leaf-miner *Promecotheca cumingi* made its sudden appearance in 1961. An estimated 30,000 acres was rapidly invaded by the pest. The attack was so devastating that the total destruction of the coconut industry in Sri Lanka seemed a distinct and imminent possibility. In an epic example of scientific co-operation and effective logistics, the new Ministry of Plantation Industries assembled nearly the totality of entomological talent available in the country for a concreted and harmonised attack on this new threat. Suitable parasites were imported from Fiji and Singapore, an insectary was established in Colombo (the focal point of the pest attack) to avoid transfer of the pest to the more concentrated coconut areas North and Eastwards, and strict quarantine and sanitation methods enforced. In a few months and after thousands of parasites (*Dimmockia javanica* and *Pediobus parvulus*) had been multiplied and released, the scales tilted in favour of the industry. Within a year or two, the pest had all but disappeared as dramatically as it had descended. Total cost of operations-less than US dollars 30,000 for an industry worth well over $30 million each year.

Less spectacularly but just as relentlessly, the Division continues to combine the use of parasites and predators field sanitation and judicious use of chemical control methods in the management of other major pests (e.g. the Leaf Scale) and the weed *Eupatorium odoratum*. For the control of red weevil, insect traps and systemic insecticides are used, for black beetle, the viral agent Baculovirus is being tried out. Experiments have also been done on the bacterial pathogen *Bacillus thuringiensis*.

Until recently, the Institute maintained three insectories but in 1977, with the successful control of the leaf miner, the one at Colombo was transferred and in 1978, the cyclone all but destroyed the other in the Eastern Province. Only the one at Headquarters continues to function.

A major problem to which attention is being given is the problem of "Leaf Scorch". This is akin to, but no where near as serious as, any of the "diseases of unknown etiology" that plague the the coconut palm in several other regions of the globe.

Another concern is the phenomenon of "duds" or unproductive palms which are distressingly common. Our principal hope is that we would discern remediable metabolic disorders as the cause of these two problems.

Plantation industries in Sri Lanka have always been deeply quality conscious. Such traditional attitudes have found application to the coconut industry as they have to tea and rubber as well. Consequently, the major export commodities — desiccated coconut, oil, fibre and shell charcoal have enjoyed good reputations and favourable prices in world markets. Copra, though now not exported, probably takes the first place for quality among producing countries.

Effective laboratory services for monitoring the produce, assistance in upgrading quality, produce testing and grading and the control of marketing and export arrangements seek to ensure the maintenance of this superiority.

The future

Curiously, coconut seems to suffer from a general paucity of precise information within the producer countries, of the basic features of growth and performance of the palm itself. Significantly, there are very few research centres concerning themselves with coconut palm physiology. In recent years, there have been some steps towards remedying this situation, notably by studies of the biochemistry of the nut and its edible components and efforts to evolve a technique for the vegetative propagation of palms. This latter is recognized as a potentially powerful tool to support and extend the efforts of coconut breeders.

The coconut palm is doubtless foremost among crop plants in the multiplicity of products that it is capable of providing. Hitherto unfortunately, the overwhelming emphasis applied to the conventional coconut products entering into world commerce, has tended to obscure the immense potentialities available for it to yield more products of nutritional and utility value within the producer countries themselves. It may be argued that pre-occupation with coconut as an oil crop or as merely a provider of industrial raw material is almost misguided. In Sri Lanka and perhaps elsewhere, coconut performs an often unrecognised yet vital role in meeting a a large part of the protein needs of rural people and in providing sugar substitutes and beverage products for a large part of the population.
In economic terms, it will be no surprise if it is found that these "incidental" values will surpass the earnings from the conventional articles of commerce now obtained from the palm.

From the point of view of providing basic nutritional needs, the coconut kernel is an unbeatable material. Combining as it does, extremely favourable quantities of fat, protein and assimilable carbohydrate, it also possesses excellent texture, a good proportion of fibre as roughage and a highly acceptable, nutty flavour. In coping with protein malnutrition, it has the special feature, that unlike most other protein-rich foods which capriciously perform better in countries already possessing an adequacy of protein, coconuts grow best in those very regions where the protein is most needed (less developed countries in the tropics).

Perhaps the only constraint to advocating a greater, utilization of coconut as food is the fear that surrounds the linkage between partially saturated oils such as coconut oil, cholesterol and coronary disease. However, it has to be acknowledged that this supposition is based largely on circumstantial evidence that falls somewhat short of proof.

Coconut research has progressed to varying extents along several lines which can confidently be expected to yield advances in the near future.

On the agronomic side, there will be an increasing availability of information on the most effective utilization of production inputs (mainly fertilizer).
This will arise from a better understanding of the fundamental physiology and growth characteristics of the coconut palm and its reactions to different climatic, soil and management factors.

In breeding, there will be accelerated testing of world collections of coconut varieties (or types) and the evaluation under comparable conditions, of these and their hybrids in various possible combinations.

A breakthrough in the field of tissue culture or other means of vegetatively propagating elite palms, will place in the hands of coconut breeders, a potent technique for the rapid multiplication into "clones" of identical desired genotypes. This will also help in many other research sectors.

With escalating costs of petroleum products, the most economic and effective means of using farm energy and synthesized fertilizers, are bound to develop.
This would result in a heightened concern with agro-economic parameters in relation to coconut culture.
An area where this will find application is in the field of mixed farming, multiple-cropping and intercropping where hitherto a vast store of empirical experience has been used to a considerable extent.

Increasing costs and difficulties in procuring farm labour will lead to considered mechanisation, subject to constraints dictated by simultaneous needs to conserve energy inputs.

Sophisticated techniques using refined instruments and isotopic materials will certainly lead to practically important gains in understanding water and fertilizer needs of the coconut palm.

Future advances on the production side are bound to be dwarfed by the unexploited possibilities that exist in the field of processing.

There are already encouraging signs that unconventional uses of the palm and its products are being seriously considered. In fiercely competitive markets, success depends on cheapness, quality, consistency uniform availability, versatility in use and several similar product attributes.

It is impossible to do more than take a glimpse at some of the potentials that will emerge for a diversified use of the enormous variety of products that the different portions — some of them hitherto virtually wasted — of the coconut palm could provide.

Sri Lanka, foremost among the producer countries, has been extravagant in the direct consumptive use of coconut kernel. It is estimated that traditional extraction methods can leave no less than a half of the oil and protein unextracted. Hence it is certain that suitable methods of extracting and preserving (e.g. canning) of coconut milk, will progress with the existing technology, until it becomes a commonplace processed commodity.

Work in the Philippines and elsewhere has shown the possibilities of evolving processing methods that will preserve and extract the oil, proteins and carbohydrates in one composite and continuous process. The protein fraction in particular would be the most versatile in its use for protein enrichment of cereal and bakery products and in non-dairy creamers, beverages and similar uses.

Producer countries could also move towards a greater share of processing profits by moving away from desiccated coconut alone to such products as toasted, candied, sugar coated, salted and canned kernel products. By an extension of this trend, the endosperm at the "jelly" stage would be a strong candidate for the preparation of syrup-based conserves.

Coconut palm inflorescence sap is richer in sugars than most expressed cane juices. The flow is relatively profuse and with suitable, and essentially, simple precautions, the sap could be evaporated to yield a sugar of highly acceptable qualities. The partially inverted sap is already widely employed to produce treacle and jaggery. By slight modifications, a very good imitation of "Golden Syrup" is easily prepared.

While on the subject of sweeteners, mention should be made of the potential coconut offers as "honey bee pasture". Ample quantities of pollen available year round and exceptionally copious and sweet stigmatic exudates, must doubtless provide a bountiful source of food for bees.

Coconut oil has had a long traditional role as fuel for domestic and festive lighting. The intriguing report of its successful use as an automobile fuel while not being entirely a surprise — offers the exciting possibility of a rapidly renewable and cultivable energy source.

Great scope also exists for a systematic economic use of the several wastes incidental to the process employed in the production of traditional export commodities. The most notable are expeller oil-cake, coconut water and fibre dust.

Copra cake may contain sixteen per cent of sucrose in a form which allows of its ready extraction with boiling water. The sugar is virtually useless to the livestock commonly fed on this material. Improved copra-making and expelling technology could help to yield the protein-rich expeller cake in a directly consumable form.

The use of coconut water (which may contain around 2% to 4% of dissolved sugar) for the cultivation of fodder or food yeasts is a clever exploitation of a biological concentrator where ordinary physio-chemical methods are impractical for reasons of cost. Sadly, not much information is available from the Philippines on this study which was pioneered by that country. The use of coconut water for the production of the delicacy 'Nata de Coco' is already well established.

The use of fibre dust as a soil-conditioner or as a bulking agent in the production of bricks or the manufacture of particle board is of vital importance to any country with a sizeable coir industry.

New needs and modes will also stimulate the industry to widen its offerings of coconut palm based products. Research activities have also to develop with due heed to the realities of socio-political factors in underdeveloped countries such as constitute the world's coconut producers. Thus intensification, modernisation and innovaton at all stages in the cultivation, processing and marketing of coconut must proceed in a co-ordinated and harmonious fashion.

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The Tea Research Institute of Sri Lanka

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The Tea Research Institute was founded in 1925 in accordance with the provisions of an Ordinance passed in the Legislative Council of Ceylon.
The Institute was set up for the purpose of research into and investigation of all problems and matters relating to tea, and the provision and publication of information relating to it. The TRI is financed entirely by the Tea Industry through a cess levied on tea exported. The Institute is managed by the Sri Lanka Tea Board.

Research organisation

The main laboratories of the TRI are situated at St. Coombs, Talawakele, and are well equipped for basic scientific research, as well as applied research in Agricultural Chemistry, Agronomy, Entomology, Nematology, Plant Biochemistry, Plant Breeding, Plant Pathology, Plant Physiology, Plant Propagation and the Technology and Biochemistry of the manufacture of tea. There is also a Statistics Division which collaborates with the other research divisions, particularly in field experimentation. In addition to the central research organisation at Talawakele, the Tea Research Institute has outstation establishments situated in Ratnapura, Kandy, Uva and Galle districts which cater to special problems arising in these planting districts.

Research accomplishments

Since its establishment, the Tea Research Institute has to its credit many outstanding contributions to the industry. Many pests and diseases of tea have been successfully controlled. An important finding in this field was the control of the leaf-eating caterpillar, Tea Tortrix. Control was effected by intentionally spreading a parasite, *Macrocentrus homonae*, introduced from Java. This biological method of control, to this day, remains as one of the Institute's greatest achievements. A further development in the management of this pest was by evolving methods to monitor its activity in the field. This was made possible by the successful isolation, identification and synthesis of the sex pheromone of the female moth. The synthetic pheromone serves as a bait to attract male moths and by such surveillance techniques it is now possible to curtail on the unnecessary use of insecticides.

An integrated approach towards pest control is currently being adopted on tea estates thus minimising the use of chemicals. Programmes based on pruning practises and other cultural practises have been evolved to manage two of the major pests of tea namely, Low-Country Livewood Termite and the Shot-hole Borer. By evolving strategies based on cultural practises it has now become possible to totally eliminate the use of insecticides against these pests.

Perhaps the greatest service that the Institute rendered to the industry was the control of the Blister Blight leaf disease which afflicted many tea plantations in Sri Lanka. The successful control of Blister Blight saved the industry from extinction and is a classical example of the benefits accruing to an industry through research.

Recommendations for the control of Poria and other major root diseases by soil fumigation with methyl bromide enabled many estates which grappled with these problems for many years, to eradicate them altogether.

The Institute has also advised the industry on various cultural practises such as proper fertilizer application and better techniques of management, which have led to increased production.

Synthesising the information available from experiments on fertilizer carried out over the past 50 years, the Institute has made comprehensive recommendations on all aspects of fertilizer usage. These recommendations were based on the potential yield realisable from various types of tea in the different districts.

Studies on the use of urea have shown that this relatively cheaper source of nitrogen could meet up to 50 per cent of the nitrogen requirement of the tea industry. Studies have also shown that the local phosphate deposits at Eppawela is a suitable substitute for imported rock phosphate, thus saving Rs. 15 million in foreign exchange annually.

The discovery of potash deficiency in 1953 and zinc deficiency in 1962 and measures for the correction of these deficiencies were important findings. For instance, the correction of zinc deficiency by foliar application of zinc sulphate led to appreciable increases in yield at a comparatively low cost. The value of the increased yields that are obtained each year as a result of correcting these deficiencies would be many times the annual cost of maintaining the Institute.

A large number of herbicides have been experimented with over the years and estates were given precise recommendations on how to handle these chemicals and develop suitable programmes of weed management. An outstanding development in this line was the discovery that *Panicum repens* could be successfully controlled with glyphosate.

Extensive research work was undertaken on soil conservation and improvement. Various measures have been recommended to estates and increased emphasis was given to the construction and maintenance of drains and terraces for soil conservation, soil reconditioning before replanting, mulching and the planting of *Eragrostis curvula* on banks in order to minimise soil erosion.

Pruning is the most crucial operation that the tea plant is subjected to, and most deaths of plants occur following pruning. Much research effort has been concentrated on understanding the physiological and biochemical changes taking place at pruning and the Institute's recommendations to estates are based on these studies.

Vegetative propagation of tea which was pioneered and developed by the Institute has provided the industry with the means for rapidly increasing the production on an unit of land, and consequently lowering the cost of production. Whereas, the average estate yield is under 1,000 kg made tea, yields of over 4,000 kg made tea have been obtained on commercial estates with the outstanding TRI 2020 series of clones. The advent of the recently developed TRI 3000 series clones offer the promise of even higher yields.

There have been many contributions to our knowledge of the biochemistry of the tea plant and of these, the more important ones include work on chemical changes during pruning, and during the manufacture of tea, the extraction and purification of tea seed oil, caffeine, tea saponins and a variety of other compounds. An outstanding contribution has been made to our knowledge of the constituent chemicals associated with the quality, strength and the aroma complex of tea.

Within the last 15 years, tea factories have been revolutionised. The major recommendations of the Institute have been the introduction of withering troughs, the introduction of the rotorvane, the introduction of CTP manufacture, the introduction of the Lawrie Tea Processor and most important of all the introduction of the Fluid Bed Drier, conceived, pioneered and commercially produced in Sri Lanka. The introduction of the Fluid Bed Drier to the industry has revolutionized the science and technology of tea drying, resulting in a 50 per cent saving on the energy used for drying.

The TRI kept abreast of changing market trends, by developing processes for the manufacture of new tea based products such as instant tea, scented tea, liquid and carbonated tea and tea based wines and sherry. The processes have been developed up to the pilot scale of operation and are now ready for industrial exploitation.

The foregoing account is by no means an exhaustive catalogue of the Institute's achievements. Only the research that has led to concrete recommendations are touched upon, and here too, many have been omitted. In addition to this work, a large amount of information has been collected, which will be of use in the formation of future recommendations. Much of this information has been published in the Tea Quarterly and other journals.

Current Research Programme

During the past few years the research effort of the TRI has been reoriented on the basis of a multi-disciplinary approach to the major problems confronting the tea industry.
At present there are over 20 on-going research projects most of which have direct practical relevance to the industry. The projects include studies on cultivation practices, management of pests and diseases, development of improved planting material, improvement and maintenance of fertility and productivity of tea soils, optimization of agriculture within tea plantations including diversification of uneconomic tea lands into other crops, management of trees and shelter belts in tea fields, water management in tea, minimizing drought effects, weed management, weather/crop studies and on the manufacture side, continuous process for the manufacture of conventional black tea, development of new tea products and the utilization of waste products, study of the storage properties of tea, and the reduction in the cost of drying.

Advisory and Extension Service

The TRI can be justly proud of its research achievements. These achievements, however, would be only of academic interest unless the practical recommendations which stem from research findings are conveyed to, and implemented on the estates. In order to disseminate the knowledge gained from research and to maximise the benefits from research to the industry the Institute has given the highest priority to its extension service. The Institute's staff maintains close contact with the planting community by way of correspondence, visits to estates, addressing planters' meetings, conducting field days, participation in symposia, conferences and exhibitions. Estate Superintendents are always welcome to visit the Institute and discuss their problems with the staff. The publication of the scientific journal The Tea Quarterly, Monographs, Advisory Pamphlets and Advisory Circulars, etc., are other means of transmitting the recommendation of the TRI to the industry.

The over one hundred-year-old tea industry has for several decades been the mainstay of the Island's economy. The Tea Research Institute is conscious of its role and always endeavours to give of its best to this gigantic industry. Today, the industry is facing a crisis, and no doubt this would pose fresh problems. In the words of Sir John Russel, then Director of the Rothamsted Experimental Station, "As the economic conditions change and market demands alter, so the problems change, and as long as the tea growing industry continues, so long will it be necessary to maintain a Tea Research Institute with a highly competent staff to deal with the ever-changing problems as they arise".