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"Development of Natural Rubber Industry through Empowerment of Stakeholders"

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Rubber Research Institute of Sri Lanka
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PREFACE

Under the reign of British emperor, Sir Henry Wickham was commissioned to bring rubber seeds from the Amazon forests in the American continent to South East Asia. The rubber seeds collected were initially germinated in the Kew Gardens in UK and then dispatched to then Ceylon in 1876. This made Sri Lanka to be the first country to establish commercial rubber plantations in the whole world and also to commence research and development work of this crop. Though some research and development work had been conducted previously, 1909 was a special year for rubber research in Sri Lanka as a scientist was appointed to work purely on crop. This can be considered as the birth of the Rubber Research Institute of Sri Lanka (RRISL), an indispensable organization for rubber research in the world.

After 100 years of diligent service to the industry, RRISL commemorate its proud history this year by sharing its experience with stakeholders whilst gathering their views on future challenges and ways of combating them to drive the industry forward. The Centennial Rubber Conference (CRC) Sri Lanka – 2009 is a strategy used by RRISL to bring all stakeholders to one platform to achieve above objectives. Moving away from the traditional presentations of research findings, areas of significance in today's context were identified and then eminent and dynamic personnel in those areas of the industry were carefully selected to present papers relevant to their category. We are thankful to all such presenters for accepting our invitation and also to ex-senior scientists of RRISL who agreed to chair the technical sessions. The interest shown by the stakeholders to participate in the conference was the driving force for organizing CRC, Sri Lanka – 2009. In addition, guidance and encouragement of the Director, RRISL, the Chairman, RRB and the Secretary, MPI helped to make the CRC, Sri Lanka – 2009 a reality and a success.

The registration fee was set to the lowest possible to encourage more stakeholders to participate in the conference. On other hand, the use of government funding was limited. Despite the economic recession, the assistance given by sponsors was remarkable. We acknowledge the financial support given by our Gold, Silver and Bronze sponsors.

All in the conference secretariat had a rather hectic time during last couple of months to drive the conference to a success. Unexpected incidents which changed the venue and dates of the conference gave an additional workload to the organizers. However, the staff of Hilton Colombo eased the pressure by providing a professional service.

We wish to extend our sincere thanks to our Chief Guest, Hon. Minister of Plantation Industries, Guest speakers, the Secretary General of IRRDB and the Head of Economic Division of IRSG and other special invitees who kept the conference in a high profile. Also, credit should go to the staff of RRISL and outside service providers who jointly made this event a reality. We wish all participants a thought provoking and a rewarding conference which will eventually arm the stakeholders to drive the industry into prosperity contributing to the economic development of our mother Sri Lanka.

Conference Coordinating Committee

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SESSION - 1

NURSERY MANAGEMENT AND FIELD ESTABLISHMENT

Development in Rubber Planting Materials to Address Current and Future Challenges

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Introduction

The ancestors of the rubber plantations in the South East Asia were the unselected seedlings collected in the Amazon basin, transported in the form of seedlings from the Kew gardens to Colombo by Sir Henry Wickham far back in 1876. The yield potential of these seedlings was around 225 kg/h/y and the yield variation among the trees was very high. The bulk of the crop was from less than one third of the stand and this situation urged the growers to seek for vegetative propagation methods where every tree would be a high yielder and contribute to the final crop equally. Rooting of cuttings had been possible with seedling materials but limitations in mass propagation, lack of a tap root system and difficulty in inducing roots on cuttings were among the drawbacks. As soon as the first seedling trees started to flower and produce seeds, the interest on generating plants through cuttings faded away. Yet the variation among individual seedling trees was unaffordable due to the long life span of the plantations.

Cloning of *Hevea*

Bud grafting was introduced for rubber in 1917 and since then rubber was propagated mainly through grafting buds from selected clones on to unselected seedlings. Though bud grafting is a partial vegetative propagation method as far as uniformity is concerned, were superior to seedlings. Among the budded plants clones used by Sri Lankan growers at the very beginning, i.e. during 1926 -1935 were Millakande 1/1, 3/2, Wagga 6278 etc. identified from plantations based on their performance. Cloning of rubber not only improved the yields but also the crop could be predicted at planting.

Hevea breeding programme/Artificial pollination

A land mark on improvement in rubber planting material was the production of new varieties by the plant breeders through cross pollination. This process of cross pollination is a continuous activity at RRISL and superior clones with high yield potentials and other secondary characteristics such as tolerance to diseases and wind and high timber volume etc. are produced, tested and released from time to time. The first group of local clones recommended to growers were the 36 clones released with the tag RRIC from 1 to 36. Yields of these clones were about four folds of the original seedlings.

The benefits achieved by the farmers with the introduction of RRIC 100 series clones namely RRIC 100, 102 and 121 etc in late 1960's were significant since both production and productivity in rubber lands increased remarkably. In particular, the clone RRIC 100 won world recognition for the best performing clone in 1979. The clone RRIC 121 easily gives a yield of 2500 kg/h/y which is about 10 fold of the yield of the seedlings brought to Sri Lanka.

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Performance of a clone is determined by many characters of which yield potential is given priority. Sri Lankan rubber industry could reach the hill country because of the disease resistance characteristics of the new clones. Annual foliar spraying to control diseases has now come to an end because almost all of the new varieties are tolerant to common foliar diseases. The recently introduced RRISL 200 and 2000 series clones have out- yielded most of the early clones. Five clones that are released to commemorate the centennial year of the RRISL perform even better.

Quality Improvement

Improvements to planting material of perennial trees like rubber can be achieved in two directions. One is the genetic constitution which is achieved through new combinations that occur at hand pollination. The other is the physiological condition of the plant. Perennial trees possess a juvenile phase during which the growth is fast. For rubber, juvenile period is about 5 years. Accordingly, all clones that are used now have long passed their actual juvenile period, as they had been in the seedling form only right after hand pollination and they have been propagated by bud grafting since then. Any how, some juvenility is maintained as the source bush plants get pollarded annually in the budwood nursery and also the buds are grafted on to seedlings which are fully juvenile. The reason for limiting the life span of a budwood nursery to 10 years is also to sustain juvenility. All improved rubber cultivars being in mature phase of growth require proper management of nurseries in order to maintain the physiological condition close to that of seedlings.

At the beginning of practicing bud grafting for propagation of rubber, about two years old rootstock plants raised in ground nurseries were grafted using brown budwood aged 1-2 years. Growth of these brown budded bare root plants in the field was uneven and also the casualty rate was high. Then bare root budded stumps were first planted in poly bags and they were field planted at 2-3 leaf whorl stage. These plants grown in poly bags were about 3 years at the time of planting and could grow fast only for another 2-3 years in the field. This problem of reaching the mature phase early in the field was overcome to a certain extent by the introduction of green budding technique where seedlings raised in ground nurseries were grafted at the age of 6-8 months. Yet the plants had a regenerated root system and were about two years at the time of field planting.

Current Recommendation

Young budding technique introduced during 1970's guarantees an uninterrupted root system as the early germinated seeds from the germination bed are planted direct in bags. They are grafted at 3-4 months and age is less than a year when field-planted at two leaf whorl stage. From 2005 on wards use of young budding was made compulsory for all replantings and new plantings in Sri Lanka.

Further Improvement/Way Forward

The age of the tree negatively correlates with the growth. The two part bud grafted tree though has a few months old seedling as the rootstock the chronological age of the grafted bud can be 20-30 years. This affects the growth rate of the grafted tree. Trials conducted by RRISL on re-instating juvenile characteristics in mature clonal materials have given encouraging results indicating that juvenile characteristics can be reinstated in mature clonal rubber. Among the juvenile characteristics that can be seen or detected in rubber plants, the colour of the shoot, the angle of the shoot to the stock plant, the colour of the leaves, the length of the internodes, and the growth rate of the plants are some. All these characteristics found in seedlings can be seen in budded plants at varying degrees depending on the presence or absence of factors contributing to the juvenility. Use of rejuvenated budded plants has an advantage over seedlings, as budded plants always grow in to cylindrical trunks compared to seedlings where the trunk is tapered leading to shorter tapping cuts. Among the horticultural practices that are practiced to reverse ageing, hard pruning, regular pollarding and successive grafting can be adopted for rubber. Regular pollarding is already practiced in properly maintained budwood nurseries. The effect of this activity to maintain the plants in budwood nurseries in juvenile state is evident by not showing mature characteristics such as wintering and flowering, normally seen in trees in clearings after 5-6 years of continuous growth. However, in addition to this if the bud wood can be grafted successively on to fresh seedlings the juvenile characteristics can be re-introduced to a significant level. Rejuvenated material will maintain the cylindrical shape of the trunk, yet they possess other juvenile characteristic such as straight trunks, long internodes and fast growth rates which are the most important factors towards productivity improvement.

Conclusion

However, it should be emphasized that improvement in genetic composition and physiological condition of the plant should move hand in hand to achieve the benefits of the new gene combinations evolved through hand pollination. The tree is able to give its potential yield and express other secondary characteristics only if the vegetative growth is supportive. Also the production of timber in large quantities will be an added benefit which is directly related to the vegetative growth. Apart from the increased amount of latex, higher volume of timber or fire wood from the rubber tree is an environmentally important consideration.

What has been achieved through variety development so far during the past century is about ten fold of the starting material which is remarkable for a perennial tree species. Yet, no one is competent enough to guess on the upper limit of the productivity of this species. Therefore, with the blessings of all who are involved in the rubber industry, the team of scientists at RRISL will continue to offer more and more new varieties with higher productivity levels and better secondary characteristics along with improved nursery and planting techniques to boom the rubber industry locally as well as globally.

Growers' Perception on the Industry Needs on Clones and Planting Material

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Introduction

After 100 years of research and development it is appropriate to take stock of what Rubber Research Institute of Sri Lanka has achieved for the benefit of growers and the industry and what needs to be achieved in the next decade and thereafter. Growers are the most important segment in the Sri Lankan Rubber industry. There are over 250,000 people directly depending on this sector, which includes smallholders, estate owners and employees of Regional Plantation Companies (RPC) and rubber based industries.

Current Issues

Productivity

Success of rubber growers depends on the sustainable profit generating ability of their plots or plantations under varying market price regimes, which is consequential on the productivity of the resources they deploy: *viz.* trees, land, labour and the systems/processes. Apparently overall productivity of resources deployed by rubber growers in Sri Lanka is largely below our overseas competitors. However, improving productivity to compete internationally is not an impossible task. One critical factor influencing productivity in the field is the lack of adherence to process quality parameters, from collection of seed to a harvestable tree.

Clonal Material

Productivity of the tree is directly related to the characteristics of the clone developed at research level. Growers' invariable demand for better clones is therefore justifiable. Planting material is the mode of transfer of the clone with its productive features for commercial use in the field. Success at field level is therefore intrinsically linked to the ability of the grower to transfer recommended clones to the fields through the planting material used.

Ironically growers achieve less than 50% (on an average) of the latex production potential of clones, which has serious implications. As an example RRISL 121 has a potential over 70 g/tree/tapping (GTT) and on an alternate day tapping system if 320 tapping days are achieved the yield per tree (YPT) is 11 kg and the yield per ha (YPH) on such a field with a tree stand of 300 will be 3300 kg. But in reality, an annual mean YPT of 3.7 kg is achieved with a YPH of 1100 kg. Considering the uncertainties experienced in the field, growers should achieve at least 2/3 of the potential, resulting in a YPH of 2160 kg, in this instance. High incidence of Tapping Panel Dryness (TPD), leaf and root diseases associated with climatic conditions are among the concerns of uncertainities. Loss of trees due to white root disease in the wet districts is estimated between 3-5% per annum.

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What do Growers look for in ideal Clones?

Growers firstly look at the profit generation capability of the clone. The critical factor that influence profitability is the latex production capacity of the tree measured by the GTT. GTT is a clone characteristic with the ability to produce latex of high Dry Rubber Content (DRC) and high latex volume per tapping. Most recommended clones have the potential to exceed a mean YPT of 8 kg, throughout its lifespan producing a YPH in excess of 2400 kg per annum on a stand of 300 trees per hectare.

High cost of establishment and possible labour shortages deter growers from investing in replanting their lands with rubber. Even though the old tree stand generates some income, especially smallholders and the organized sector have difficulties in maintaining cash flows during the long immature phase. The 60 months immature phase is certainly a disincentive, even with limited subsidies available, to smallholders with no alternative income. From an ecological perspective the initial phases of replanting account for a sizeable soil disturbance and consequent erosion in the wet zone undulating land. A viable alternative to meet both of above weaknesses is to extend the latex harvestable lifespan of the tree.

Associated with longevity of the tree, other essential clone features are –resistance to TPD, pest and disease and ability to withstand adverse stormy weather conditions. As non traditional areas are selected for rubber growing, the need for drought resistant clones with high productivity is now established. Finally, growers look for a larger choice of clones for use in a wide range of micro climatic and soil conditions prevalent in this country. Lack of these qualities in clones, triggers off a chain reaction, starting with low productivity, high cost of production, low quality of produce, low profit margins and finally the reluctance to reinvest on rubber planting.

RRISL developed and released, several very promising clones, for commercial use over the years. But relatively low productivity levels are yet experienced commercially as growers fail to harness the potential of these clones. Some recommended clones respond to similar conditions with varying and different performance levels. There are clones that respond differently in the same locality in growth rates and resistance to diseases as well. These vagaries make growers uneasy with clones and their usefulness - RRISL 102 is one case in point. We need these gaps bridged to move towards enhancing productivity.

Planting Material Production

New clones, developed through technology interventions, with associated unique and favorable characters by the RRISL are transferred for commercial use and benefit, as planting material, to the field. Planting material from growers nurseries invariably perform way below the rated potential at researched levels. This is a serious cause for concern and is a priority to attend.

Several nursery techniques introduced by RRISL helps produce low cost planting material. But severe limitations in measuring quality of the planting material exist. The GTT of the individual planting material is virtually unknown until harvesting time- 72 months away. Due to this reason the productivity between field plants within a clone vary significantly. In a field study of a clone, it was revealed that GTT varied between 10 to 90 g with a mean of 22 grams.

On the forgoing as growers fail to harness clone potential in the field, it is construed that transfer of clone characters through planting material, is responsible for poor field productivity, and the weakest link in this critical productivity chain.

Nurseries

There are serious logistical problems in procuring sufficient quantities of quality seed for stock nurseries from the limited seed producing areas in the Island. Having procured seed from far away places, quality of which itself is not assured, nursery managers face challenges to operate within recommended time parameters to ensure that only the best reach the germinating beds. Seed formation is weather driven, has significant climatic implications on its availability and that remains a major obstacle for commercial scale nurseries.

There are no techniques to differentiate between good and bad seedlings from a large population with genetic diversity, other than by time (in days) which lends itself to different interpretations based on availability of seeds for germination. Even when keeping strictly within the specified time period, the variability in perceived growth rates makes it difficult for growers to make judicious decisions. Quality of planting material is assessed only through 'careful' but subjective observation which has obvious and severe limitations.

Inability to identify clone characteristics at the very juvenile stages (young budding) makes it difficult to maintain clone integrity in the field. Mixed clones in the field causes considerable operational issues such as in latex stimulation regimes. These are serious concerns faced by growers in their efforts to produce natural rubber and these limitations can cause problems to the industry of very significant proportions.

Future challenges

Clones

Looking into the future from a grower's perspective we need to be optimistic of the technological feats that can create the seemingly impossible. Being a small nation we need to challenge our selves to do better than the best. Consider the shrinking resources of land, water, human capital available; with regard to our future requirements – we cannot but demand for clones that will give 200 gtt at commercial scale (this is not a dream as we have already come across such trees). These clones should have a latex harvestable life span up to 40 years and will grow into huge entities of bio mass giving large volume of timber and or energy at termination of its economic lifespan.
These clones will be TPD resistant, resistant to common diseases; withstand gale force winds. Yes we are talking about genetic engineering to produce super clones and genetically modified trees.

Planting material

Growers require nursery processes that guarantees quality planting material. Tissue culture may be one option to produce large numbers of identical plant material. These plants should deliver the rated yield potential of clones commercially. Nursery quality management can be improved if traceability of the plant material in terms of YPT and disease resistance is developed and introduced.

Dependency on naturally occurring seed material for plants and buds as scion must be a thing of the past. Tissue culture plants must be available on schedule as the process can be planned to meet future demands. These plants in the field will perform exactly as expected-when managed as required.

Strategies to Address the Uncertainty in Seed Availability for Plant Production

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Introduction

The annual replanting and new planting extent of rubber (*Hevea brasiliensis*) in Sri Lanka is *ca.* 5500 hectares and therefore nearly 3 million budded plants, i.e. 9 million (*ca.* 36 MT) of seeds are required annually. According to general consensus, seed production of rubber had been satisfactory and well above the requirement of nurseries till the late 1980's in the Wet and Intermediate Zones of Sri Lanka. Since then, there have been many complains specially from the nurserymen in the Wet Zone of Sri Lanka on a shortage of seed production to a level that would affect the quality of the planting materials.

The shortage of quality seeds has led to an urgent need to increase seed production to meet current and future demands. However, seed production is the least amenable to control by silvicultural management. Therefore, understanding of variability in rubber seed production among climatic zones, sites within a zone, clones and years will allow better planning of seed collection for planting material production. Early studies in seed production were mainly confined to three clones viz. PB 86, RRIC 100 and RRIC 121. However, newer clones with high latex potential are being continuously planted. Therefore, the objective of the paper is to estimate the seed production through a detailed assessment on the currently planted clones in major rubber growing regions of Sri Lanka and find ways for the efficient usage of available seeds for plant production.

Study area

The study was conducted in nine plantations (seven from Wet Zone and two from Intermediate Zone) with 16 clones during major seed fall season from July to October, 2008 and with 3 clones in two plantations from Wet Zone in 2007. Majority of rubber lands selected for the study were of 14 years old. Three plots of 18mx12m were marked at three randomly selected places from each clearing identified and covering about 10-12 trees. In each plot, seeds were collected either daily or at two day intervals during seed fall season in each year. Though RRIC 100 and 121 were found in all study areas since latter did not show substantial seed production, RRIC 100 was used for the germination study.

Observations

Seed production varied between agro-climatic zones, among sites within a zone and also between years. Greater hectarage of seed production was observed in RRIC 100 compared to that of RRIC 121 in all the plantations except in Kuruwita where RRISL 201 showed the highest seed production. The seed production in RRIC 121 was almost zero in majority of the plantations except Padukka (1435 seeds/ha/year) and Nakiadeniya (30seeds/ha/year) of the Wet Zone and Nottinghill (92 seeds/ha/year) of the Intermediate

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Zone. Apart from RRIC 100, no satisfactory seed production was recorded from other clones in Dartonfield, Pussella, Pallegoda and Nakiadeniya estates in the Wet Zone. Nevertheless, RRIC 102 (31 900) and PB 260 (4880) in Payagala, and RRIC 133 (5100) in Kuruwita of the Wet Zone showed a considerable seed production.

The seed production per hectare in RRIC 100 was 16 157 in Wet Zone while that in Intermediate Zone was 9259. This is a deviation from the reports of the early studies where a greater seed production per hectare was recorded from the Intermediate Zone. Based on the present study, sufficient amount of seeds could be collected from the areas around Payagala, Pallegoda, Kuruwita and Padukka estates in the wet zone for seed collection.

Commencement of seed fall in RRIC 100 varied from plantation to plantation (from end of July to mid August) irrespective of the climatic region. Therefore, planning should be done to collect seeds during early seed fall commencing in July because rubber seeds are short-lived and are recalcitrant. The germination percentage of seeds of RRIC 100 collected from all the plantations during early seed fall was above 70% after three weeks from sawing.

The clonal difference in susceptibility to diseases in particular to *Oidium* and *Phytophthora,* directly affects the seed production. *Oidium* can damage flowers and young fruits completely. Infected flowers either dry prematurely or remain with deformed perianth till opening. *Phytopthora* attacks young fruits resulting in loss of fruits. RRIC 100 is resistant to both *Oidium* and *Phytophthora* while RRIC 121 has below average tolerance to these diseases and this might be also a reason for a higher seed production in RRIC 100.

Overgrown weeds in the rubber plantations make seed collection difficult and also cause collection delay. Therefore, the quantity of collectable seeds could be increased if the rubber plantations are well-weeded during seed fall season and old seeds from previous seed season are removed prior to seed collection. Daily collection of seeds is strongly recommended. Seeds should be sown in germination beds soon after collection, preferably on the same day. Seed storage even for a few days is not desirable.

In recent years, rubber clones showed a substantial flower and seed production in some plantations during off season and this phenomenon has been described as a method to mitigate the difficulties caused by seasonal nature of flowering and fruiting in *Hevea.* Therefore, attention should be made to collect seeds, if any, during December-February from the plantations in the Wet Zone in addition to the seed collection from the areas like Bibile and Moneragala of the Intermediate Zone where the major seed fall season occurs during December-February. Seeds produced during off season were also found to be good and similar to seeds collected during the main seed fall season irrespective of the climatic zones.

Currently, the total area of RRIC 100 above 12 years of age and under RPC management (only 40% from total area under rubber in Sri Lanka) is ca. 21 545 ha and of this, 697 ha is found in Mawanella, Polgahawela, Kegalle and Kurunegala areas where a higher seed production is generally recorded. If the average seed production of mature RRIC 100 is considered to be around 10 000/ha, only 981 ha is required to fulfil the country's seed requirement. Therefore, a shortage of seed production for next 10-15 years could not be expected as RRIC 100 performed well in seed production even under unfavourable weather.

For the efficient usage of available seeds in the Wet Zone, suitable areas should be identified from mature RRIC 100 fields, proper weeding should be done during July-August and daily collection of seeds should be made from the first day of seed fall. Also, it is required to sow seeds on germination beds soon after the collection. Whenever there is a shortage of quality seeds in the wet region during main seed fall season, arrangements should be made to collect and transport seeds from comparatively drier areas such as Kegalle and Kurunegala. However, more attention should be paid to collect seeds during December-February from Bibile and Moneragala areas where ample seed production is generally reported. In such instances, undue delay in transportation should be avoided. Further, to prevent any short supply situation of quality seeds in the future it is advocated to establish seed gardens preferably in the Intermediate Zone using RRIC 100 mixed with other potential seed producing clones.

SESSION - 2

SOIL FERTILITY MANAGEMENT

Soil Management Practices for Environmental and Economic Sustainability

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Introduction

When rubber lands are uprooted for replanting, changes detrimental to the environment and soil can happen resulting in poor soil characteristics. This condition is more severe in undulating to steep terrain where rubber is mostly grown. When old stand of rubber is uprooted it results in bare patches of soil where surface runoff can be detrimental to the soil. Also, during the early years after planting, young rubber plants provide very little protection to the soil mainly due to the partial canopy cover. Therefore, the soil erosion likely to happen in rubber plantations can be greater. Soil, being a non-renewable resource, should be conserved for the benefit of future generations. It should be conserved properly to avoid depletion of essential plant nutrients and organic matter from the fertile top-soil. Unfertile soils cannot sustain economic yields even with high doses of inorganic fertilizers. But at the same time soil degradation can be minimized to a great extent by proper agro-management to reflect an effective near alternative to the humid tropical forest ecosystem. Therefore, proper use of land and development of effective agronomic practices must be ensured in order to preserve the productivity and fertility of the soils of rubber growing areas.

Agronomic practices towards environmental sustainability

Pre planting practices

On hilly and steep terrains, rubber should be planted on contours, with minimum disturbance to the inter-row areas which help water to remain for longer period on the soil surface thereby increasing the infiltration of rain water into the soil as well as to minimize surface run off. Surface runoff and soil erosion in the rubber lands should be further minimized by drains and silt pits and these pits can also act as a series of storage tanks, trapping water from surface runoff and through fall, which can be readily used by the rubber trees during dry weather. The construction of silt pits mid way along a slope seems to create a kind of catchment effect at that level, with rubber trees benefiting from the stored water in these pits. The effect of this is more pronounced during the dry periods. On very rocky land, where it is impossible to cut continuous drains and silt pits, the soil and moisture conservation needs should be at least partially fulfilled by the construction of stone terraces.

Cover crops

The role of leguminous cover plants in efficient soil management is of considerable importance. This is brought about by the addition of organic matter to the soil, through natural decaying of leaves, stems and roots. Further, a good ground cover can prevent the direct impact of raindrops, thus preventing the breakdown of soil structure. A ground cover on the soil surface is also known to serve as a cushion against the pressure exerted by raindrops. *Mucuna bracteata* is a leguminous creeper, introduced to rubber cultivation in Sri Lanka recently and the performance of this cover crop indicates that green matter and litter production is three times higher than that of traditional cover crop *Pueraria*

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phaseoloides. Also, *Mucuna* exhibited 45cm and 106cm thick layers of green matter and litter respectively, compared to 15cm and 36cm thick layers in *Pueraria*, for green matter and litter, respectively. A significantly high contribution of N, P, K and Mg was made by both green matter and litter of *Mucuna* compared to that of *Pueraria*. Soil analysis indicated a relatively higher build-up of nutrients, organic carbon and microbes in the soil under *Mucuna* in comparison with *Pueraria*. Among the two species, the highest moisture profile storage capacity of 25.8 cm was observed under *Mucuna* for 90 cm profile depth. There was an increase of 41% in the moisture storage capacity as compared to the soils under *Pueraria*. It was found that growing *Mucuna* resulted a better soil physical condition than *Pueraria*. Data on soil loss indicates that growing *Mucuna* can minimize soil loss significantly, in comparison with *Pueraria* and also weed infestation was lower under *Mucuna* and reduce weeding cost by 70%. *Mucuna* substitute 50% of N fertilizer requirement of rubber and thereby cut down fertilizer cost by Rs. 31,000 per hectare during the economic life span of the tree.

Mulching

Although management of ground covers is an important aspect in rubber cultivation for the preservation of soil fertility and soil conservation, at the same time ground covers may compete with young rubber plants for moisture and nutrients. Therefore, a circle of about one meter radius around each rubber plant is clean weeded to avoid competition. This can lead to some degree of soil degradation around the base of the rubber plants due to the exposure of soil to adverse climatic conditions. Providing a protective layer of mulch on the exposed bare soil patches and around the base of the rubber plant with a suitable mulching material can therefore, be considered as a better agronomic practice. Apart from serving as a cushion against the direct impact of rain drops, a layer of mulch on the soil surface reduces the flow velocity and carrying capacity of the runoff. Marked increase in infiltration rate with mulching indicates that the soils have higher water intake capacity thus reducing runoff and minimizing erosion. Generally, there is an increase of 43% in the moisture storage capacity under mulching and in drought conditions more water retains in the soil under mulch. Mulching also tends to reduce the rate of evaporation of soil moisture thus allowing moisture to remain in the soil for a longer period. Therefore, it is possible to eliminate or at least minimize the adverse effects of moisture stress by mulching. During the early stages (1-2 years) of planting rubber, it is evident that more moisture is lost by transpiration from the leguminous covers than what is conserved by the litter it produces. However, eventually with the luxuriant growth of leguminous covers, more moisture will accumulate under the cover plants. It is, therefore, very important to find a way to reduce evapo-transpiration losses along the planting row during the early stages of a rubber plantation. This can be achieved very effectively by mulching. Weed growth in general, can also be reduced markedly by mulching. Especially during a drought period, by reducing the weed growth, mulching reduces unnecessary evapo-transpiration and thereby conserves soil moisture.

Application of organic matter

In addition to chemical fertilizers, the Rubber Research Institute of Sri Lanka (RRISL) encourages every rubber grower to apply organic materials to improve the physical, chemical and biological properties soil. The improvement in soil conditions reduce soil degradation, increase fertilizer use efficiency, increase water and nutrient holding capacities, reduces unproductive immature period and finally increase yields. They could be applied as a mulch or by incorporating into the soil depending on the type of organic material. The establishment rate, observed after field planting of young budding plants was 98% with the application of organic manure (50g per poly bag) compared to 85% without organic manure been added to the polybag. Similarly, when 3kg of organic manure is applied to the planting hole, the field establishment rate was 98% compared to

80% without organic manure application to the planting hole. Girth after 12 months of planting was also higher in both instances with the application of organic manure.

Twining environmental and economic sustainability

Nutrient management in rubber cultivations has gained greater importance in recent years because of two major reasons: firstly, rubber plantations are no longer raised in virgin forest soils and secondly, most of the plantations are either in the second or third cycle of replanting. Large amounts of mineral elements are locked up in the process of biomass accumulation and are lost through timber during replanting. Gradual depletion of mineral resources through cycles of replanting warrants appropriate nutrient management and at the same time, more and more marginal and depleted soils are being brought under rubber cultivation and under such situations proper soil and nutrient management are essential to sustain higher growth during the immature period. Further, the introduction of high yielding clones of *Hevea* has no doubt provided a mechanism to reduce the unproductive period, given a set of specific conditions. It is also a known fact that the implementation of a proper package of agro-management practices in accordance to soil and climate is a pre-requisite to the realization of the plant's potential growth capacity. In this package, economics and efficiency of fertilizer utilization are vital elements.

The most popular method adopted by the rubber growers to control costs during adverse trading conditions are curtailing of soil management practices. This approach could result in productivity losses both in the short and long term. Hence, such methods whilst not capable of solving the problem will also result in lowering of profitability when rubber prices recover. Any shortcomings in soil management practices will have a huge negative impact on land productivity and hence the profitability. Therefore, the soil management practices should be undertaken using the available funds effectively and efficiently.

Present and Future Needs in Soil and Fertilizer Management: Growers Perception

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Introduction

Fertilizer is an important factor in any agricultural operation. To improve productivity and yields, it is necessary to maintain the fertility of the soil at the highest level. Therefore, fertilizer becomes an indispensable item of crop production. In rubber cultivation, it has become an expensive item in the cost of production. Considering today's market prices for rubber, many rubber cultivators and even large plantation companies are not able to afford the cost of fertilizer for their rubber fields. Therefore, to maintain high yields and even improve on the present levels of productivity, continuation of the soil fertility improvement is a must. For this purpose, the application of fertilizer becomes unavoidable. In Sri Lanka, since a large volume of artificial fertilizer is imported, very valuable foreign exchange is needed for its purchase. Therefore, it is necessary for us to find cheaper alternatives to maintain the soil fertility levels without adversely affecting the crop yields.

Most artificial fertilizer is applied to the soil in which the crop is cultivated and the subsequent chemical changes occur in the soil to convert the complex chemical compositions to simple forms which could be absorbed by the root system. Therefore, the efficiency of fertilizer uptake would depend on the condition of the soil. Hence, what needs to investigate are the methods, which could improve the soil structure and thereby the uptake efficiency, at an economical cost. By the improvement of the uptake efficiency, the quantity of fertilizer applied could be reduced and thereby the cost too could be reduced.

Methods to improve nutrient uptake efficiency

Introduction of soil inhabiting fungi

The roots of most plants growing throughout the world in nature or in cultivated state are intimately associated with such soil inhibiting fungi. These intimate associations are termed "Mycorrhiza" and they create the link between plant roots and the soil and plays in important role in the acquisition of mineral nutrients by the plants. The Mycorrhiza can be classified into two main groups, broadly based on the arrangement of the vegetative Hyphae of the fungus in relation to the host root tissues. These are Ecto and Endo Mycorrhiza. Of these, the endo mycorrhiza type – Arbuscular myhcorrhiza symbiosis (VAM) is the most common in nature. In the AM associations, the fungi colonize the cells of the root system in order to obtain carbon from the host plant. In addition to the growth within the root system, the fungi also develop a net work of external hyphae. These hyphae absorb and translocate mineral nutrients and water from the soil to the root system of the host plant. Due to this reason, the plant receives the additional nutrients and water for its healthy growth, free of stress factors which normally affect the plants. The efficiency of nutrient and moisture absorption also increases for the benefit of the plant. Mycorrhizal plants therefore grow better even in nutrient limiting conditions by the more

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efficient use of available nutrients and moisture in the soil. These Arbuscular Mycorrhiza associations significantly increases the absorbing surface area of the feeder roots (enlarges the depletion zone), availability of nutrients to the trees, tolerance to drought stress and resistance to root diseases. The suggestion is to introduce the Arbuscular Mycorrhizal (AM) fungi to the rubber soils and thereby increase the rate of nutrient and moisture uptake by the rubber plants. Due to the higher absorption rate, the quantity of fertilizer applied could be reduced and the frequency of applications in immature rubber reduced. This would result in immediate cost reductions.

Introduction of highly soil efficient bacteria

.By the efficient decaying process of leaf matter in the soil by the action of bacteria, the soil structure improves by increasing the soil carbon levels. This in turn assists in the uptake efficiency of fertilizer and moisture available in the soil. Such bacteria are area specific and soil specific. Hence, they need to be carefully selected and introduced to the soil to avoid other complications. Introduction of highly soil efficient bacteria to accelerate the decaying process in the soil as a pre-condition stage of compost preparation will also be useful.

Slow release fertilizer

There were certain experiments and scientific tests carried out earlier by the RRISL of this type of fertilizer, but was not recommended for commercial use due to its high cost. There are many advantages in this type of fertilizer like improvement of uptake efficiency due to the slow release of nutrients into the soil as per the actual needs of the plants, reduction in the frequency of application and quantity, particularly in the immature rubber, reduction of the cost of application and the reduction of labour for application.

Application of bio-fertilizer

In the early forties after the 2nd World War, there was a wrong notion amongst farmers and plantation managers, particularly in Third World Countries, that the extensive use of chemical fertilizer was the way forward towards high yields which are rich in quality. The developments across the world in the following decades have proved that this belief has no scientific basis. It has been proved that replacing chemical fertilizer with bio-fertilizer has far reaching consequences such as reducing environmental pollution, more cost effective and increases yields with high quality produce. Though Sri Lanka is the 73rd country in the world to begin the use of Bio-fertilizer, other countries like USA, China, India, Philippines, etc have started its use many years before. The USA started as far back as 1901. In some provinces of China the use of Bio-fertilizer is mandatory.

There are tremendous advantages to the Sri Lankan plantation crops with the use of Bio-fertilizer. There are useful bacteria identified which are capable of fixing atmospheric nitrogen and solubalizing insoluble phosphorous which are now used in the formation of Bio-fertilizers. When chemical fertilizer is applied, it gives nutrients in high concentration and when added continuously, micro-organisms in the soil are destroyed. Studies are done to create plants that by themselves are able to fix nitrogen from the atmosphere (that is to convert nitrogen gas into nitrates) that can be absorbed by the plant's metabolic system. At present only certain plants called legumes are naturally able to do so. Even legumes require the aid of symbiotic bacteria for this function. Therefore, such a development would drastically reduce the use of chemical fertilizer required by plantation crops. This product has to be perfected for it to be ideally suited in different soil conditions. In plantation crops which have received chemical fertilizer for many years, the introduction of bio-fertilizer has to be done gradually over a period of few years.

Future research needs

- To identify the most efficient and beneficial soil inhabiting fungi to be introduced to rubber soils in different soil types and locations at an economical cost.

- Identify the optimum quantity of fertilizer to be applied to achieve the maximum yield of rubber by improved soil efficiency.

- To isolate suitable soil fungi and bacteria to be introduced to rubber soils to expedite the process of decay of leaf matter which would improve the soil structure and fertility.

- Facilitate the large scale multiplication of efficient fungi for commercial use on rubber plantations. At present the technology for producing and distribution of Arbuscular Mycorrihiza inoculums in large quantities is poorly developed in Sri Lanka.

- Production of Bio fertilizer for commercial scale application in rubber areas to improve soil structure.

- Stop the excessive use of artificial fertilizer in rubber soils to prevent soil toxicity and high costs.

Advances in Nutrient Management in Rubber and Way Forward

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Introduction

In Sri Lanka most of the rubber plantations are either in the third or fourth cycle of replanting. During this period loss of top soil due to erosion, removal of nutrients through latex yield and timber has caused gradual depletion of mineral resources. This phenomenon has urged research on fertilizer requirement for Rubber in Sri Lanka. This paper reveals advances in nutrient management in rubber and future challenges.

History of fertilizer application to rubber

From the dawn of rubber cultivation, crop residues, wild plant materials, animal wastes and some by products of agro industries have been traditionally used to improve and maintain the soil productivity. After sometime growers believed nitrogen (N) and potassium (K) fertilizers are useful to the improvement of growth and yield of rubber and phosphorus (P) fertilizer was of little or no advantage. Also, most of the recommendations at that time were not based on any research work but were on the experience of the growers. In 1933, the first experiment on use of fertilizer was initiated in the research station at Dartonfield, Agalawatta and the out come of that study was published in 1939, with the first recommendation of N, P and K manuring for rubber. The recommendation to apply ammonium sulphate, rock phosphate and muriate of potash containing fertilizer mixtures for immature and mature rubber was done in 1942. In the view of the increase in the incidence of magnesium (Mg) deficiency in fields, addition of Mg to the NPK mixtures in the form of commercial Epsom salts was recommended in 1954. Earlier work on the studies of Sri Lankan soils did not stress the importance of the soil parent material. Based on the differences in parent materials, the rubber soils of Sri Lanka were divided into seven important soil units, in 1969. In 1980, it was recommended that urea can be effectively used as the N source for both immature and mature rubber. The use of fertilizer does not however mean that the practice of using any type and amount of fertilizer are necessarily beneficial. Optimum growth and yield can be expected only by ensuring a much balanced nutrient supply and not by the indiscriminate application of fertilizers. Indiscriminate applications have often been found to depress the yield and growth instead of improving it.

Recent advances in fertilizer use

Nursery stage

Use of fertilizer in nurseries is necessary to produce the maximum number of vigorous and healthy plants from a unit area within the shortest period. For the tender young budding nursery plants soluble fertilizer mixtures to provide N, K, Mg and IRP are recommended. Fertilizer recommendations for young budding nurseries were revised to increase the production of quality plants with continuous application of 100ml of liquid

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fertilizer at 4-weeks intervals during the entire production cycle. Also, high-grade Eppawala rock phosphate (HERP) is recomended as a basal fertilizer.

Immature stage

In the immature phase of rubber, proper manuring is essential for vigorous growth and early tappability. In poor soils, girth and girth increment of rubber show positive response to N and P fertilizer application. Data on girth, girth increment and percentage tappability have shown consistent increases in growth resulting in shortening of unproductive period through fertilizer application. Application of N, P and K fertilizers in the form of urea, rock phosphate and muriate of potash respectively reduce the unproductive period of RRIC 100 series clones by about 18 to 24 months. Further, the N requirement of rubberin the immature phase is greater than what is given through chemical fertilizer. This deficit in N fertilizer needs to be provided by establishing a recommended legume cover crop.

Systematic application of fertilizer throughout the pre-tapping phase leads to satisfactory levels of total and available P build up in the soil and such accumulation of phosphate during the immature period is likely to be sufficient to sustain the P requirement of the rubber tree at least during the early productive (mature) period. Though IRP was the only source of P recommended for immature rubber, in the recent past ERP was recommended instead saving considerable amount of foreign exchange. Also, use of dolomite, the cheapest source of Mg available in Sri Lanka was recommended for immature rubber in year 2008. Further, to increase labour use efficiency it was also recommended that dolomite and urea fertilizers can be applied to two separate points during the same application. The RRISL emphasizes that in all fertilizer mixtures involving immature rubber the correct K-Mg balance needs to be achieved. Incorrect ratios would not only result in the occurrence of visual deficiency symptoms but also would result in retarded growth of young plants, thus prolonging the immature period.

Mature stage

The response of mature rubber to fertilizer through yield increases is highly dependent on the nature of soil and agro-management practises and hence differs widely. Yield increases in the existing mature plantations could be obtained with increased applications of nitrogen in the form of urea. Application of nitrogen to mature rubber under Sri Lankan conditions has been proved to be beneficial even in the areas with good agronomic management history. Yield responses to N is closely followed by responses in girthing. Increased application of K fertilizers may give yield increases in some areas but P and Mg applications can be discontinued for several years if these fertilizers had been applied regularly during the immature phase. On the other hand, low level of K fertilizers may be used in areas with high K content, such as the soils derived from biotite gneiss (micaceous parent material). For areas where long dry spells are apparent particularly for the non-traditional rubber growing regions like Moneragala, K fertilizers were doubled for increased water use efficiency under stress conditions and thereby increasing the growth as well as yield of *Hevea.* It is important to mention that the ERP deposit in the country was discovered in 1971 and a recommendation of 100% ERP for mature rubber was done in 1980. Application of dolomite lime is not recommended during the mature phase, due to the direct effect on plugging index thus reducing latex flow rate and time ultimately resulting in to reduced yields. The current approach for nutrient management in mature rubber is to monitor leaf nutrient status and follow discriminatory fertilizer recommendations. The combination of soil testing and leaf analysis provide a better basis for offering fertilizer recommendation than blanket application of fertilizers. Development of this diagnostic technique has made it possible to asses the discriminatory fertilizer requirements for individual mature rubber fields and make site-specific fertilizer recommendations more accurately enabling efficient and economic use of fertilizer. Also the scenario of decreasing rubber prices and the ever increasing fertilizer prices in the market, prompted the RRISL to develop a new fertilizer recommendation for mature rubber.

Site specific fertilizer recommendation for immature rubber, fertilizer mixtures for new clones, micro nutrient studies, bio film application for rubber growing soils and slow release fertilizers are some of the thrust areas for future research in the area of nutrient management of rubber.

SESSION - 3

PEST AND DISEASES

Efficient Management of Economically Important Diseases

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Introduction

Efficient management of economically important diseases is a basic necessity for sustainable rubber farming. Presently more than 20 potential diseases are evedent in Sri Lanka and the severity of each disease varies according to the prevailing climatic conditions, locality planted and the clone cultivated. In this paper, management strategies of the economically important rubber diseases are discussed, emphasizing current practices in Sri Lanka. A special effort is made to highlight the importance of the adoption of correct cultural practices and use of genetic resistance in disease management as cultivation of rubber is a marginally profitable venture today.

Economically important diseases in rubber plantations

The maladies identified as economically threatening diseases with the establishment of the rubber cultivation were the Oidium leaf fall (OLF), Colletotrichum leaf disease (CLD), Phytophthora leaf fall (PLF), bark rot (BR) and white root disease (WRD). These diseases were present island wide and a considerable effort was made to control them.

One of the interesting features of the disease scenario of the rubber tree is the considerable change that took place in the relative importance of diseases during the last several decades. Presently traditional rubber diseases like OLF, CLD, PLF and BR have become less significant and cause minimal damage to the rubber plantations in Sri Lanka. The secret behind this is the successful breeding programmes undertaken since 1960s with the aim of producing tolerant clones to the economically important diseases present during that era.

Unfortunately, a few of these new breeds succumbed to new pathogens threatening the natural rubber plantation industry in the country. One of the important changes in the disease scenario of the rubber tree which affected the Sri Lankan rubber growers was the spread of Corynespora leaf fall (CLF) during the latter part of the 1980's. This disease was first detected in several poly bag nurseries in Kalutara and Galle districts. Within two years CLF had spread to all rubber growing districts severely affecting RRIC 103, one of the prestigious clones produced by the Sri Lankan scientists. By the year 1988, around 4,500ha representing 2.2% of the total area under rubber in Sri Lanka were severely affected causing repeated defoliations and die back of trees.

Non adoption of correct cultural practices during the establishment and management of nurseries also predisposes the rubber plants to new pathogenic attacks. Spread of collar & hypocotyls rot, target leaf spot disease, and foot canker in nurseries in late 20th century resulted due to growers' negligence of recommendations made by the Rubber Research Institute of Sri Lanka (RRISL).

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Another interesting feature was the spread of some maladies at epidemic levels during the recent past which were considered as insignificant problems during the 20th century. The examples are the cockchafer grub attack in Avissawella and Ratnapura regions, spread of basal rot in most of the rubber growing regions and the most recent invasive mealy bug attack in Kegalle and Gampaha districts.

Control methods for diseases on rubber

Chemical control

The most popular method of controlling rubber diseases in the past in Sri Lanka was the use of fungicides. Chemical control was widely accepted since the beginning of the 20th century without paying much attention to the economic viability, health hazards and environmental pollution. However, these chemicals effectively destroyed the fungus eliminating the disease.

Today use of fungicides to control leaf diseases is generally confined to the nurseries and immature clearings. Canopy disease management using chemicals encounters several limitations. The major problem faced is the low economic benefits as rubber cultivation is not economically very attractive today. The height of trees and hilly terrain of the rubber lands pose further limitation to the spraying or dusting of chemicals demanding high powered costly machinery. Difficulties encountered in prediction of disease epidemics also play a significant role in canopy disease management as most of the recommended chemicals have preventive rather than curative effect. However, application of chemicals to avoid black stripe during South-West monsoon period and use of soil drenching fungicides to manage white root disease are still recommended.

Breeding for resistance

The economical and most appropriate approach to manage diseases in rubber plantations is the use of clones resistant to diseases. Thanks to the effort of Breeders and Pathologists, presently RRISL is in a position to recommend *Hevea* clones resistant to all economically important canopy and panel diseases. The present replanting trend shows that only the resistant clones are being accepted by the growers. Further, the dream of the expansion of rubber cultivation to high elevations (above 300m) has now become a reality purely due to the production of *Oidium* tolerant clones by the Sri Lankan Breeders.

The disadvantage of breeding for resistance is that the interference of dynamic changes of the pathogen with the long lasting resistance of this perennial crop resulting in the breaking down in disease tolerance. An ideal example for this is the recent (1995) CLF epidemic on the clone RRISL 110. This outstanding rubber clone, which succumbed to CLF in 1995 was a resistant clone in 1985 when CLF was first detected in Sri Lanka.

Adoption of correct cultural practices

Appropriate recommendations on correct cultural practices have been provided by RRISL since its establishment. Most of these recommendations are very simple, inexpensive and easy to follow. However, some of these important recommendations are not being followed by the growers. This may be due to negligence, lack of awareness or shortage of labour. This non-adoption of recommended practices results in unexpected problems leading to total destruction of field plants and nurseries.

Biological control

In general, biological control is interpreted as the reduction in the incidence of disease caused by a pathogen through an agency of any other living organism. In some cases antagonists to pathogens are added to the environment, in other cases the environment is modified to favour antagonists.

Decades of research led by the Pathologists have provided a wealth of information on biology and epidemiology of the *Hevea* pathogens. Successful biological control measures have been developed to control several economically important rubber diseases based on these information. Management of white root, abnormal leaf fall and black stripe diseases are classic examples for biological control.

a) Management of white root disease
In the management of white root disease an environment is created by adding Sulphur (sprinkling of 110g of Sulphur to the soil around planting hole) that is more conducive to the antagonist flora in the soil.

b) Prevention of abnormal leaf fall and black stripe
Incidence of abnormal leaf fall and black stripe could be drastically reduced by restricting Oidium leaf disease control in the months of January and February. The fungus infects flowers resulting in poor pod set. This prevents the build up of required inoculum potential to cause *Phytophthora* epidemics in May to September.

Conclusion
Presently a combination of crop sanitation, disease resistance, cultural, biological and chemical procedures are being recommended for management of maladies of the rubber tree in Sri Lanka. It is improved that this integrated approach minimizes the disease incidence at a very low cost with minimum damage to the environment. The methods described in this paper to control several diseases involve no cost at all.

Industry Perception on Pest and Diseases of Economic Important

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Introduction

Plantation sector today is saddled with many crises such as, scarcity of labour, threats of pests and diseases, poor trading and finally very low investment for replantings.

The industry sustained in spite of all above challenges over the last 3-4 decades. It is obvious that these problems should be tackled strategically in order to ensure the sustainability of the industry in future.

This paper is aimed to address the issues on economically important pests and diseases with the personal experience in the rubber industry. Factors underpinning such issues and the reactions of the industry under challenging situations are also dealt. Further, emphasis is given to the research and development activities of the Rubber Research Institute and the deficiencies of them at the level of implementation.

With limited pests present in rubber plantations, only the diseases are dealt here under following categories.

- Leaf Diseases.
- Panel Diseases.
- Root Diseases.

Leaf Diseases

Only the following major diseases have been identified for discussion.

- Corynespora leaf disease
- Phytophthora leaf disease
- Odium leaf disease

Corynespora leaf disease is very common in rubber nurseries. The estate personnel who are involved in plantations are well conversant in controlling measurers at nursery level. In the event of any outbreak in mature areas, it is very essential to update their knowledge on precautionary methods and control. Therefore, more efforts should be taken to educate the personnel in the plantations to tackle any unforeseen circumstances.

The pathogen, *Phytophthora* is again more important as it is directly responsible for Bark rot in tapping panels. Although the planters and the rest of the personnel in the industry are aware of this fact, very less attention is paid for controlling and spread of the Bark rot. The number of trees that are lost annually is increased by large numbers. This situation directly lowers the productivity of the plantations. Therefore, the Rubber Research Institute should strengthen their field training work, in more regular manner with the assistance of the Regional Plantations Companies.

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Oidium attack on immature leaves is considered to be favourable to a certain degree, as it will have a natural control of *Phytophthora* leaf fall, hence the Bark rot incidences. This factor seems to be ignored by the people due to lack of knowledge.

Panel Diseases

This is mostly the Bark rot caused by *Phytophthora* infection. At present very little precautions are taken to control the spread of the disease. Further details of Bark rot was discussed under the Phytophthora leaf disease.

Although the infected area of the bark can be treated to prevent any further spread of Bark rot disease, the damage area of bark will not be renewed perhaps forever affecting the productivity of the tree.

Therefore, preventive measurers that should be undertaken at estate level should be strictly followed. Field staff responsible for implementing the recommendations seems to be not capable of identifying the disease correctly.

Root Diseases

In the rubber sector, the only root disease, which is economically important, is White root disease caused by *Rigidiporus microporus*. This was well under control for last two decades. There had been no much incidence of the disease over this period. However, this disease has increasingly been reported in recent past, particularly during the last 2-3 years. Factors concerned are,

- Ignorance or lack of knowledge.
- Substandard field work
- Mechanization of uprooting and preliminary work.

This is an alarming situation, as the ignorance might cause severe damage to the industry. It is revealed that in the plantation sector most of the executives who are employed at present have joined after privatization of the estates. White root disease was well under control at that time and even after some time after privatization. Therefore, it was not a necessity for new comers to pay much attention to the disease, which has not been heard of. Hence, prevention measures were not practiced.

Secondly there were no investments made for replantings after privatization due to very poor trading. Rubber replantings were not undertaken at least for ca. 05 years. Therefore, many executives could not gain any experience on the management of root diseases. Further, certain plantations and smallholdings could not replant their uprooted senile rubber for a long period

Another contributory factor for the root disease is the mechanization of uprooting and preliminary work. Improper use of Backhoe machines in uprooting does not remove the rubber roots satisfactorily. In this process, rubber tree is not pulled out from the ground with the complete root system. Roots remaining underground facilitates for the infestation of white root disease.

It is inevitable to use the mechanical devices in initial land preparation activities to address the problem of labour scarcity. However by doing so, the standards of rubber plantations cannot be ignored. Close supervision in field activities will minimize the ill effects.

In addition to the research, the Rubber Research Institute of Sri Lanka is expected to play a very dynamic role in educating people in the rubber plantation sector for the eradication of White root disease. This should be the case for other important rubber diseases though they are fewer in numbers.

Suggestions

- Assess the risk factors, and risk areas of possible threats of pests & diseases.
- Strengthen the awareness programme for Planters and Small Holders in the Plantation sector to update their knowledge.
- Create an awareness of economically important pests & diseases among the other stakeholder Organization and obtain their participation.
- Look into the possibilities of Research & Development work with stakeholder Organizations to attract Local and International funding.
- Activate Regional Scientific Committees to update the of growers knowledge on current issues and Research & Development, activities.
- Strengthen the quarantine laws to prevent possible threats of transmitting deadly diseases to the Country.

Conclusion.

Rubber Industry of Sri Lanka has a great potential as an Industrial Raw Material. The most important factor is to create an environment for all Stake Holders to work together for the development of the industry.

Today there are constrains in respect of Research & Development cultivation, marketing, but it appears, that very little contribution or participation to tackle these problems, collectively by the Stake Holders.

The expectation today is to work for a common Goal, with all Stake Holders, to ensure the sustainability of the industry.

Ways to Eradicate Menace of Mammalian Pests & White Root Disease

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Introduction

The menace of mammalian pests and white root disease have been identified as two major causes for poor tappable stand in rubber plantations. Plantations adjacent to shrub jungles are subjected to frequent invasions of wild animals and can be destructive to the rubber plants irrespective of their age. A large number of mammalian pests inflict severe damages while rodent attack has been identified as the most destructive. Further, Deer (Olu Muwa), Rabbits, Monkeys or Bandicoots can also cause damages to rubber trees. White root disease caused by *Rigidoporus microporus*, the most destructive root disease of rubber in Sri Lanka is seen in approximately 4% of the cultivated rubber lands. It has been found that in flat rubber lands from a single white root diseased plant, approximately 55-80 trees can be destroyed during a period of 15 years. There is a potential to increase the number depending on the location and on the number of initially infected plants. This clearly shows the potential threat from this disease to the economy of the industry.

Management of Wild Boar and Porcupine Attack

Wild boars cause a variety of damage. The most common damage is rooting (grubbing) the young plants causing total destruction of them or severe damages to the bark by their violent behaviour. Consequences of the damage will be the injuries to the bark or ring barking. Porcupines too gnaw or eat the bark repeatedly. The deer, rabbits and monkeys eat leaves and twigs while the bandicoots damage the root system.

The controlling systems adopted are based on the legal status, cultural and religious background, the technology availability and most importantly the cost involved. The conventional methods used for protecting plants from harmful animals are erection of border fences, keeping the clearing well weeded, hanging white polythene strips on fences or plants, employing sound producing gadgets and spreading cut hair pieces.

RRISL Recommendations

Pest damages

Concerted efforts are on at RRISL to derive efficient management strategies especially for wild boars and porcupines. According to the trials conducted by the Plant Pathology & Microbiology Department, application of chillie or tobacco powder or TMTD (Tetra Methyl Thiurum Disulphide) in a latex base was effective in preventing damages caused by the animals to a considerable extent. Several drawbacks were observed in the preparation of the of the latex based mixture and also in the process of application. Hence experiments are in progress to recommend a ready made mixture for the growers and the formulations under investigation show very promising repelling capabilities.

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Physical methods such as grid fencing on the ground around the plant using barb wire or chicken wire is also tested to keep them away from young plants. Use of Bamboo strips around the plants is also effective to keep the porcupines away. White polythene wrapped around basal part of the plant was proven to be effective in controlling the damages caused by rabbits.

Based on world literature, several successful technologies are available but the main drawback of these methods is the high cost. One of the most effective technique is the use of an electric fence. The fence should at least consist of 4 parallel horizontal wires stringing all the way around the clearing. DC current is used to give enough of a shock to repel the animals.

Fencing using concrete posts and barbed wire has been successful to exclude wild boar especially in estates. For this method to be successful regular maintenance is also required. Use of baited traps has been employed in boar control operations throughout the world. A pre-baiting programme should be conducted before trapping programme is operated. Hunting is used in certain countries and shooting has on certain occasions proved an effective method of control. In some countries, well managed wild boar hunting seasons are also used to control their population. Successful reduction in the number of mammalian pests has been achieved by poisoning too. The method has been proven to be effective and low cost. Sodium monofluroacetate (A 1080) is a commonly used chemical but can be harmful to non target animals too. Hence, currently no poisons are approved and registered.

Estate owners must accept the fact wild-boar and other mammalian pests damages could occur in cultivations situated in areas bordering shrub jungles and should therefore plan for a long-term control programme. Cost is an important consideration for any control programme and hence integration of different methods may be considered.

Repellents can be used to keep the animals away. Use of mechanical barriers has also proven to be successful. Intermittent hunting pressure too will simply move the animals away from the plantations. On top of the need to control the mammalian pest populations the social, cultural, religious and legal background of our country will also affect the phenomenon. However an effective management of a population of mammalian pests can only be achieved by concerted integrated action over a large area otherwise animals will continually re-invade from neighbouring areas.

White Root Disease

White root disease caused by *Rigidoporus microporus* is the most destructive root disease of rubber in Sri Lanka. The pathogen affects both mature and immature clearings killing the plants and spreading towards the adjoining healthy trees by root contact with infected stumps or root debris. The above ground parts show symptoms of yellowing and buckling. To confirm the condition, the collar region of the plant should be examined for the presence of whitish mycelial strands (rhizomorphs). At latter stages more intensive foliar symptoms may appear showing premature flowering and pod set during the off season. With the well establishment of the fungus the fructifications develop at the ground level.

Prevention of the disease is very important rather than curing it as this disease can cause loss of trees lowering the plant density and leaving unproductive patches of lands.

Therefore, action need to be taken during preparing the land for cultivation, uprooting the old stand (pre planting), planting and post planting, for effective control of the disease.

Removal of all the infected logs including roots up to pencil thickness is mandatory. We should be vigilant for any foliar symptoms in plants of a new clearing, as early identification is important for treatment to be successful. Sometimes, the plants acting as vectors or transmitters (Kanda/Alstonia) of White root disease will remain in the lands spreading the disease very quickly to the new healthy plants. White root disease incidence in rubber lands, which are intercropped should be managed more vigilantly since, the infection gets transmitted to a larger area through the dense root network of all crops.

However, if detected early, the disease can be effectively controlled by applying a systemic fungicide. Regular collar inspection in risky areas would help to identify infected plants at an early stage enabling the chemical control using systemic fungicides such as tebuconazole or hexaconazole. The treatment to a mature infected tree may not be successful if the infection has damaged the entire collar area ring-barking the tree. In such instances, it may be worthwhile to uproot the entire tree without leaving any roots under ground.

SESSION - 4

EXPLOITATION

Exploitation Methods to Sustain High Performance under Changing Scenarios

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Introduction

In the earliest tapping systems of rubber such as 'V' cut and herringbone system, there was no much concern paid either to protect the bark of the tree for long-term tapping or to use labour efficiently. Comparatively, labour was cheaper and planters could dictate their terms on workers. Although the herringbone system was extended to full and half spiral cuts thereafter, these systems were also designed only for short-term high latex yields. There were some instances where, the bark in the lower six feet of the trunk had been removed in a year of daily tapping. High prices prevailed for rubber would have been the driving force for such intensified tapping and also some seedlings were capable of producing yields as high as 35kg per year. Inability of trees to withstand the high intensity tapping was an eye opener to the planters and scientists who then inclined to investigate the suitable levels of the factors underpinning the sustainable yield. Tapping systems which have been developed to date are the outcome of all those efforts. This paper is aimed to present the most suitable exploitation methods to address the challenges faced by rubber growers in today's context.

Challenges in today's context

Quality of tapping in most Sri Lankan plantations is comparatively better than that of most of other rubber growing countries. Sustainability is imbedded in the Sri Lankan culture and therefore, Sri Lanka is among the few countries which have been capable of maintaining rubber plantations for 30 years in commercial level. However in today's context, the sustainability of exploitation is to be looked at in a holistic manner not only covering agronomic feasibility but also taking into consideration the economic viability and social acceptance. Cost of production (COP) is escalating with increased labour and management costs. On average, the contribution of labour in exploitation and management to COP is ca. 37.5 % and 41.2 %, respectively in the regional plantation companies of Sri Lanka. Labour rights are stronger and also, the rubber industry should compete with other industries for the same. The option of diversifying the rubber plantations to other profitable ventures are also looked into. Therefore, sustainability of exploitation depends on how effectively those factors are dealt with. Basically, labour usage needs to be minimized to reduce COP; competitive remunerations and working conditions are to be provided to attract workers; and the bark of the rubber tree should be consumed carefully.

Mechanistic approach to speed up the tapping operation and thereby to reduce COP is still beyond the reach. Among the options available, Low Intensity Tapping (LIT) systems provide the most appropriate means to address above issues. Either tapping frequency or the cut length or both are reduced in LITs. In order to compensate the yield loss associated with reduced intensity, yield stimulants are applied and that increases the yield

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per tree per tapping. Stimulants increase the latex synthesis and slows down its coagulation resulting in prolonged latex flow and increased drainage area once tapped. Despite the same yield per tree per year of the traditional alternate day tapping (d/2) is expected in LITs, the reduced tapping frequency in particular is considered to be less stressful to the tree allowing sufficient regeneration time for latex. With LITs, each worker can be allocated with greater number of trees and their wages can be increased due to higher yields in each tapping. Also, bark consumption per unit time period is less. Nevertheless, from the management point of view, different LIT systems need to be applied in accordance with the growth/tapping stage of rubber tree, processing type of latex and availability of workers.

Low intensity tapping systems for early stages of tapping

In the commencement of tapping in a new clearing, instead of traditional alternate day tapping (d/2), tapping frequencies of either tapping once in three (d/3) or four (d/4) days on the base panel can be applied with no reduction in the overall yields. In the d/3, 2.5% of ethephon is applied 4-5 times per year whilst the same ethephon concentration is to be applied monthly (except in defoliation period) in the d/4 tapping. Evidence within the country showed that average yield harvested from a tree in the d/3 and d/4 systems have been in the region of 4.3 kg per year and which is ca. 6% lower than the yields of the d/2. In the d/3 and d/4 tapping, yield per tapping day is ca. 50% and 100% higher than that of the d/2 showing the potential for reduced cost of production and increased wages to latex harvesters. Further reduction of the frequency, i.e. tapping a tree once in six days, is also possible with the monthly application of 5% ethephon but there may be a yield loss of ca. 16 %. At the moment, RRISL is working on the stimulation schedule for the d/6 frequency to correct this yield loss. Tapping systems like d/6 or once a week tapping allow rubber smallholders with off-farm involvements to tap their rubber fields during the weekends. These systems can continue until economical yields can be harvested from the base panels as high panels are opened thereafter.

Low intensity tapping on high panels

After the completion of BI-1 panel, tapping is generally intensified and therefore, high panels are tapped along with BI-2 panel under d/2 frequency. The mentality of intensified tapping drives the workers to consume the bark hastily and haphazardly resulting in the waste of the bark particularly in virgin high panels. Moreover, in some instances, careless tapping in base panels speed up the panel usage and hence tapping on BI-2 panel begins earlier than recomended, so with under developed renewed bark. Control Upward Tapping (CUT) with a short cut and reduced frequency (i.e. d/3) provides efficient utilization of high virgin panels which have greater yield potential than renewed base panels. In CUT, two options are available – stimulation with either ethephon (CUT-ET) or ethylene gas (CUT-EG). Obviously, the former is quite easy to be applied and ethyphon is considered to be a slow releasing compound of ethylene which is the ultimate stimulant of rubber latex. With monthly application of 5% ethephon, ¼ of the circumference of the tree (1/4S) in high panels is opened for tapping in CUT-ET. Special jackets are to be fixed on the bark in CUT-EG for periodical injection of ethylene gas (e.g. RRIMFLOW, G-flex). This requires only 1/8 of the circumference of the tree (1/8S) for tapping and hence CUT-EG leads further saving of the bark. Also, yield response to stimulation is quite fast. Despite these advantages, field application of the CUT-EG demands high level of attention particularly for the repairs of leaking jackets and calibration of the gas cylinder. Further, CUT-EG systems are rather expensive in Sri Lanka and hence its cost effectiveness is questionable unless the dealers bring down the cost reasonably. Although manufacturers' recommendation is to inject the ethylene gas once in 10-13 days in CUT-EG, the gassing frequency of 30 days was found to be suitable for Sri Lankan clones. Anyhow, gassing frequency of 15 days could be applied during last two years in tapping (i.e. 2 years before uprooting).

Conclusion

Obviously LIT systems are useful to address the current issues in the exploitation of rubber. However LIT systems are yet be experienced by the majority of Sri Lankan planters. Basically, correct level and method of stimulation, application of rainguards, panel marking to ensure the correct level of bark consumption, proper control in bark depth and correct placement of tapping utensils are essential for the effective use of LIT.

Current Issues and Future Challenges in Rubber Harvesting

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Introduction

In the present day context, rubber plantations have to be competitive with other allied industries in terms of labour use and the costs involved. Harvesting is an important agronomic practice in the rubber plantations which is also labour demanding and incurring high costs. Therefore, this paper aims to pinpoint the current issues in this subject that need attention to make the rubber industry viable with regard to costs and labour use.

Labour use

Rubber harvesting since inception is being traditionally undertaken manually. With the extents of rubber increasing and with yield improvements in highbred clones, the requirement of workers too has increased. With increased opportunities for labour in other industries, a severe shortage of workers for harvesting is being encountered by both plantation and smallholder sectors. There is also a reluctance in the younger generation being attracted for rubber tapping and the industry is now faced with an ageing work-force. Harvesting of *Hevea* rubber is highly skilled and the rubber tappers have to be adequately trained to perform harvesting to get the best returns and also to protect the rubber trees to get optimum economical results over the total life span of the tree.

Traditionally rubber harvesting has been with specified intensities in tapping, commencing from a lower 67% or 100% intensity with a minimum of a half spiral of the rubber tree being tapped for a period of 18 years and during the last 6 – 7 years being intensified and finally moving up to 400% intensity. To maintain this system of tapping, a fair work-force is required on an average of approximately one tapper/ha. With the increasing wages and to overcome the shortage of harvesting workers, it is necessary to introduce new tapping systems to reduce the workers required which in turn will also reduce the cost of harvesting.

With the shortage of workers envisaged in the near future, the plantations would not be in a position to harvest the potential of the estates due to lack of workers. In the current method of skilled tapping where a correct tapping slope has to be maintained and the depth which defers from tree to tree, the required skilled manual workers would not be available especially with the growth of the industry. With the present tapping methods, unless the virgin bark tapping is perfectly undertaken avoiding wounding of the cambium, the bark renewal will be poor resulting in low yields during the balance 50% of the life span of the tree tapped on renewed bark. Therefore, the potential yields of the newly developed high yielding clones too would be hampered due to an unskilled workforce. New tapping methods/systems with stimulation would be the way forward in reducing the worker requirement.

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Tapping utensils for convenience

The tapping knife introduced to the industry at the inception is still the same and with advanced technology of the current era, mechanical harvesting needs to be introduced. The initial work of this concept commenced many years ago but a recommendation for commercial use is a long felt need.

Transport of latex

The current method of harvesting and transport of latex is labour intensive since the practice is to collect latex from tree to tree and the main mode of transport continues to be by head carrying which is also a social stigma where the current generation is resistant to be harvesting employees in the industry. This also compels the latex harvesters to restrict the harvest since it becomes a part of their employment to head transport the harvest to the weighing sheds which is in an average distance of 01 km. Therefore, the transport of produce should be more organized reducing the burden on the harvesting workers.

The road network of the rubber fields remains the same for the past several generations of rubber, which does not cater to the present requirements. The road network at the time of planting is a critical aspect to be analysed since we should not depend on manual transport in future. This would also help all field activities and other connected agricultural practices. The ideal condition would be for the harvesting workers to collect the latex in plastic cans which could be kept by the road-side where the cans would be picked up in a tractor trailer and transported to the processing centres, thereby releasing the tappers from the field it self.

Another suggestion would be inter-connected latex flow lines from the trees down to collecting centres which may sound expensive but could be more feasible when comparing the labour availability and costs for transport and also the intake/tree need not be restricted to avoid difficulties in carrying latex. This also needs to be connected with planting distance to be more cost beneficial.

Land selection

At present, there is not much emphasis on ergonomic during land selection in rubber plantations. Rubber is being planted in high terrain where the productivity is comparatively low and is difficult for all connected agricultural practices to be undertaken resulting in low yielding fields with less stands. Therefore, it would be prudent to select land, giving priority to the flat areas, where the production and productivity both will be attractive and could compensate to the low yielding fields in highly undulating lands.

Rain interference

Another important aspect in harvesting is the weather conditions where tapping has to be discontinued on rainy days. This creates a doubt on the part of the workers of continuous stable income and is being attracted to alternate employment. There is also a considerable loss of crop due to tapping not being possible with rain interruption. Rainguards have already been introduced to minimize the days lost due to rain but the tapping panels continue to be wet during the height of the monsoons. This situation creates a doubt in the tapper of not being able to undertake tapping on a particular day and since the majority of the tappers reside in the surrounding villages they do not report for tapping on such doubtful days. Therefore, the rainguards need to be more advanced with a full water proof system where tapping would be possible as per the theoretical tapping intensity.

Due to many reasons including weather interruptions, pre-coagulation is a normal occurrence especially during the monsoon. Currently anti-coagulants are issued to tappers, which needs mixing and dilution. A much user friendly method for anti-coagulant use which could be in the form of a capsule or a tablet where the tappers could conveniently use would also be more effective and would help to increase primary grades of natural rubber being manufactured resulting in increased revenue.

Conclusion

At present the growers find it difficult to achieve the potential yields obtained in trial research blocks due to many of the reasons mentioned above. If the theoretical yields are achieved, this industry would be lucrative and many more growers would give priority for natural rubber as a source of revenue in the agriculture sector of the country.

Tapping Panel Dryness: Is it a Threat to the Potential Productivity of Novel Clones?

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Introduction

Tapping panel dryness (TPD) of rubber is a physiological disorder which was first discovered in Brazil in the 1880s. The simple definition of a TPD affected rubber tree is "a tappable rubber tree from a recommended clone, unable to give economic yields through any recommended tapping technique, due to non-production or obstruction in latex flow in the drainage area of the tapping cut or punch". Though the yield loss due to TPD is highly variable it sometimes exceed even 50%. Hence, TPD is a disorder of great concern to the rubber growers today. The incidence of TPD depends on various plant and environmental factors such as age, clone, level of agro-management practices and quality and frequency of exploitation according to the literature available to date.

The first record on TPD in Asian plantations goes back to 1914. According to the early reports, the incidence of TPD was very little in Sri Lanka indicating that tapping systems which minimize the incidence of TPD, had been practiced at early days in Sri Lanka where the world's first Rubber Research Institute was established. Although TPD has been reported since the commercial level exploitation of the rubber tree for latex, its close association with high yield potential will aggravate the seriousness of this problem; because all the rubber growing countries in the world continue to develop high yielding clones for enhance profitability.

Symptoms of TPD

TPD with different symptoms and caused by different factors have been reported, but all end to the common symptom of panel dryness at the end. Late dripping has been identified as a common symptom at the onset of TPD, but this is not true for all clones. Generally, trees may either be partially or completely dry and brown discoloration of cortical tissues may or may not occur. Cracking of bark below the tapping panel is commonly noticed but rarely this symptom appears above the tapping panel. Coagulation of latex inside vessels and partial emptiness of latex vessels are also reported. Abnormal cell division due to the excessive meristematic activity leading to formation of nodules, burrs and tumours, and cracking of bark are also evident. Histological symptoms such as formation of cross walls, latex vessel tylosis, partial or complete coagulation of latex within the vessels and damaged lutoids are also common features of TPD.

Causes of TPD

It has been observed that high rubber yield is positively correlated with TPD indicating that there is a correlation between high metabolic activity and TPD. Clonal response to TPD has been reported from all the rubber growing countries in varying degrees for their native clones as well as for foreign clones. Complete shut down of isoprene biosynthesis pathway as a result of inadequate supply of ATP is possible in completely dry trees as

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rubber biosynthesis has been reported as a highly energy demanding process. Earlier it was thought that limitations in sucrose supply hinder latex production leading to TPD. But now it has been found that limitation in ATP in converting sucrose into isoprene is the critical factor causing trees to become unproductive. Increasing the intensity of exploitation appears to increase the metabolic activity of plants and thereby leading trees to become TPD.

Today there is evidence to prove that TPD is due to the physiological stress of the plant resulting from the production of free radicals and reactive oxygen species (ROS) such as super oxides, hydroxyl radicals and peroxides leading to oxidative damage in the TPD affected bark tissues. It has been found that the wound-induced endogenous ethylene production was high in TPD affected trees indicating that wounding itself induces the oxidative stress. The equilibrium between the oxidative stress and the ROS scavenging mechanism of the tissue determine the degree of oxidative damage and thereby the level of TPD. The physiological stress resulted from regular wounding in the tree bark triggers the ethylene biosynthesis pathway and produces ethylene with the byproduct of cyanides. Ability in detoxification of cyanides varies from tree to tree depending on the stage of stress they are in. If the rate of detoxification is slow, it leads to cell damage resulting TPD.

In relation to the biochemical and molecular biological studies, decrease in total protein content and variation in the protein pattern in the bark tissue of affected trees have been observed in response to the onset of this syndrome. Various protein markers of TPD have also been identified and the major protein marker described is 'small rubber particle protein' *i.e.* SRPP (*Hevb3*) which is 24 kDa in size. Furthermore the genetic transformation and regeneration of plants with the gene coding for superoxide dismutase (SOD), the enzyme detoxifying ROS, has been reported. Discovery of these protein markers and transgenic plants will facilitate to develop resistant clones for TPD through the molecular techniques in the future.

As previously mentioned, various factors such as the clone, tapping system and intensity, stimulation practices, agro-management practices and soil conditions are known to influence the incidence of TPD. Over exploitation *i.e.* high frequency, long cuts, deep tapping and over stimulation can aggravate the condition of TPD. With the introduction of vigorously growing, high yielding clones and tapping systems with the use of yield stimulants the growers need to be more conscious of this disorder in the future.

Remedies for TPD?

The chemical formulae which are said to cure TPD have not been very effective in curing or controlling this situation. Therefore, the best strategy is the prevention of this disorder rather than taking efforts to control once the trees get affected with this syndrome. This is very important particularly with the development of the high yielding clones with high metabolic activity and obviously, as there are no effective remedies to control or cure TPD to date. Therefore, production and planting of good quality plants, planting only in desirable soils, adoption of better agro-management practices throughout the lifespan and latex harvesting to cause minimal stress to the plant will definitely reduce the incidence of TPD leading to enhanced productivity and profitability from rubber cultivations.

SESSION - 5

ADAPTIVE RESEARCH & TECHNOLOGY TRANSFER

Technology Refinement to Address the Smallholder Needs

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Introduction

Rubber is grown mainly in the low country wet zone of Sri Lanka. The area under the rubber cultivation in the country expanded from 708 ha hectares in the year 1900 to 122,240 hectares in 2008. Although no smallholder participation was present in early stages of rubber cultivation, at present there is a substantial extent belonging to smallholders. Further, the majority of these rubber smallholdings (87%) are below 1 ha.

Despite its continuing importance, the performance of smallholder sector has been poor and, this is often attributed to years of negligence, lack of proper planning and failure to adopt research findings. The production systems of smallholdings are rather complex and subjected to physical, biological and socio-economic influences. Smallholders consistently diversify the use of their resources depending on the interactions among their various activities, not only within the crop but also among other enterprises or activities on-farm and off-farm. To improve rubber production in smallholdings, a change is required in the present approach in solving the smallholder problems. Basically, the impact of new technologies has been more towards increasing productivity in commercial estates rather than smallholdings. This is because the main target of large scale plantations is to maximize the profit with no apparent scarcity in resources. Smallholders would rather optimize the use of available resources to meet their priorities of which high productivity of rubber is not always the case. Therefore, technologies developed on-station for maximum productivity may not be relevant for smallholders. In order to cater the smallholder needs, research activities have to be reshaped addressing the problems and constraints in rubber smallholdings. In this context, adaptive research facilitates to refine the existing technologies as for the smallholder farmers' needs, particularly in a wider dimension.

Adaptive research

In detail, adaptive research programs evaluate and refine, or modify if necessary, the technology developed at research stations to fit better to a particular condition meeting the needs of farmers. It gathers information on the economic viability and social acceptance of new technologies. Further, adaptive research expands scientists' and extension workers' understanding of the local farming systems, practices, and problems through field visits and interaction with farmers in real world situations and thereby, facilitates "bottom-up" planning of agricultural research in place of the conventional "top-down" approach. The ultimate objective of this line of research is to get a group of researchers, extension workers and smallholders to work together within a given farming model to identify appropriate technologies to suit their farming conditions. In this system, the farmer himself becomes an active participant in the technology generation process.

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Adaptive Research programmes in rubber smallholdings

First national level adaptive research programme in Sri Lanka was launched in 1989 by RRISL after forming its Adaptive Research Unit. It covered all traditional areas of rubber cultivation in the country and comprised of clone evaluation, intercropping, use of rain guards, soil and moisture conservation, use of organic manure, rubber effluent as a fertilizer, disease control, use of yield stimulants, young budding and rubber processing. The programme was able to convince the smallholder farmers on the utility of those technologies. Nevertheless, rubber cultivation within the wet margin has declined rapidly with urbanization and land fragmentation. It was required to increase the production of natural rubber to meet the local and international demand thereby to strengthen the national economy. In view of increasing the rubber production, moderately dry areas (Intermediate zone) of the country have been focused for rubber cultivation. The present target is to cultivate 30,000 ha of rubber in Uva and Eastern provinces. The majority in these regions are smallholder farmers who are engaged in shifting cultivation. Virtually, these farmers have no permanent income sources and therefore, adopting rubber based farming systems in these regions is one way to address livelihood needs of people. In order to explain the complexity and then the practical use of adaptive research, this paper aims to highlight the steps taken to establish rubber in smallholdings in Eastern province with farmer participation in cultivation, extension and research.

Adaptive research in Eastern province

This particular programme was geared to expand the rubber cultivation to the intermediate zone of the Eastern province in an efficient manner targeting the lands left after the shifting cultivation in this region with collaboration of the peasant community whose livelihood depends largely on seasonal crops grown on these lands. Research activities included identification of farmers' problems and constraints, refinement of the technologies on agronomy and extension of rubber cultivation for the area and establishment of research extension smallholder linkages. In this process, firstly, a review of secondary data available, interviews and surveys with key informants and smallholders and site visits were made covering potential areas. Secondly, rubber was established in limited smallholdings of a selected village and then an agronomic assessment on initial establishment of rubber and SWOT analysis in the village were conducted.

Based on the information gathered initially, the rubber cultivation in the Eastern province was mainly targeted to the areas under the Intermediate zone in soils predominant with Reddish Brown Earth and Immature Brown Loams. Initial growth and establishment of rubber in smallholdings showed the potential adoption in rubber cultivation in the region. The mean survival of rubber plants for all sites established was recorded as 75% together with an annual plant girth expansion rate of 7.4 cm. According to the rainfall pattern, the time of planting rubber and the frequency of fertilizer application was adjusted. In order to minimize the impact of dry spells on plant growth, well-grown poly-bagged plants with good root system were used for planting together with other cultural practices such as deep planting and mulching. In particular, agric residues of maize, upland rice and rice straw were introduced as mulching materials. The period from May to August was quite dry and virtually, there was no rain in June and July. During this period bamboo irrigation technique (*i.e.* similar to pitcher irrigation) was also introduced to overcome the severe dry spell.

Lands appeared to be not a limiting factor and farmers were highly interested in cultivating rubber in the area concerned. However, problems associated with land ownership needed to be sorted out enabling farmers to obtain existing rubber subsidy benefits. Extension programmes were to be strengthened to educate farmers on crop management practices of rubber. Poor roads to villages and lack of financial assets with farmers were the constraints for expansion process. Timely distribution of planting materials, fertilizer and subsidy payments were essential for proper establishment of rubber in this region. Farmers' socio-economic needs were also identified.

Since initial agronomic assessments were in favour towards rubber cultivation in this region, a rapid livelihood analysis was carried out to assess the impact of this intervention in rural livelihood. Unlike seasonal crops which were confined to specific periods depending on rainfall pattern, rubber demanded labour throughout the year with an average of 5.5 days per hectare per month In absence of other agricultural activities, farmers generally allocated time on rubber cultivation. However, there was a competition between rubber and other crops for labour at the beginning of Maha season (i.e. September to November). Expenditure was mainly for subsistence and agriculture related activities and it was generally a low figure. However, their traditional New-year celebration in April required an additional amount. Due to the dependency on seasonal crops, the income varied largely from month to month. Knowing the benefits, farmers geared to cultivate rubber and that was the main reason for the high level of success in the expansion process of rubber cultivation in the Eastern province.

Conclusion

In the effort of upgrading the smallholder sector, the adaptive research programmes are essential to refine the technology available for large scale growers to suit with smallholders' needs. In recent past, such a programme was launched in the Eastern province and it was able to build up a researcher-technology transferor-farmer coalition for successful rubber cultivation in the region. Undoubtedly, this enables to increase rubber production, livelihood of the rural poor and tree cover in the country.

Strategies for Efficient Technology Transfer in the Smallholder Sector

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Introduction

Sri Lankan rubber sector comprises of smallholdings and large estates. The large estates are managed by Regional Plantation Companies. Smallholder farmers' main economic objective is to maximize their family income in contrast to that of large estates who look for maximizing returns on their investment. The smallholders often use family labour and their own or borrowed cash in farming operations.

Smallholdings occupy nearly 57% of the total extent but they provide only a share of about 42% to the national rubber production. According to available statistics the overall productivity of rubber in 2008 was 1350 kg/ha. However, reliable statistics are not available with regard to productivity levels of the smallholder sector. Anyhow, the comparative variable low yields in smallholdings are mainly due to poor adoption of recommended agronomic practices owing to unstable income levels coupled with escalating cost of production. Unsatisfactory extension service rendered to smallholder farmers is also among the major factors, which affect on adoption of recommendations. This paper presents some problems and experiences together with the strategies and other possible approaches, which could aid in penetrating the barriers towards successful technology transfer in the smallholder rubber sector.

The extension network in the smallholder rubber sector

The need for an advisory service to cater to the rubber smallholders was realized in late 1936 with only 2 officers and a clerk and within 10 years another 8 officers were appointed and by 1948, this number was further increased to 47. The Advisory Services Department (ASD), which was under Rubber Research Institute of Sri Lanka (RRISL) till 1981, became a separate Department under the Rubber Research Board. The Rubber Control Department was established to enforce the legislative provisions of Rubber Control Ordinance No 63 of 1938, which was later repealed by the Rubber Control Act No 11 of 1956. The Rubber Control Department was upgraded to Rubber Development Department (RDD) as a result of amalgamation of Rubber Control Department with the Advisory Department of Rubber Research Board in 1994. However, after analyzing the situation prevailed in the rubber smallholder sector a necessity was arisen to re-establish an -extension wing under RRISL. As a result, the Advisory Services Department was formed with 35 extension officers selected from RDD to cater the smallholder sector in all rubber growing areas except Moneragala. This department together with the RDD is currently responsible for the technology transfer to the rubber smallholders to improve the adoption rate of recommended technologies to enhance productivity and profitability of their rubber lands.

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Strategies to overcome barriers in effective technology transfer

There is no guaranteed procedure to ensure the transfer of any technology because of the variability of situations and conditions surrounding the popularization process. However, improve the smallholder performance the attention need to be focused on the following; *viz.* a) development of appropriate technology, b) transfer of developed technologies together with relevant knowledge, c) promoting avenues for adoption and diffusion of transferred technologies, d) creation of a suitable environment for implementation and e) revitalizing Government policies.

Identification of problems and development of recommendations only by the researchers themselves resulted in low adoption levels in most instances, which are not affordable, especially for small-scale farmers. There have been several adaptive research trials in farmers' fields conducted by RRISL in collaboration with the farmers. However, better success would have been achieved through collaboration by means of understanding farmers' perceptions, local knowledge and specific problems. Meaningful dialogues between researchers, extension workers and farmers to share experiences gathered at the ground level are of immense importance for development of appropriate technologies. Information through surveys, extension research and participatory approaches can be used to incorporate knowledge and experience gathered in generations by local communities for better success. Also, setting up of some coordinating bodies with representatives from relevant stakeholders will help strengthening the research-extension-farmer linkage. All technologies recommended for smallholders need to be tested for the smallholder situation through on-farm research methodologies followed by an economic evaluation. Further, capability of the technology in improving the productivity of small farmers, farmer friendliness, affordability with less capital involvement, efficient use of natural resources, low cost post harvest handling, short term direct benefits, site specific nature, sustainability and environmental friendliness should be considered in technology development.

The developed technologies need to be penetrated to the farmer level with proper planning by the respective extension managers and operators. In this respect, farmer participation towards a satisfactory level would be of paramount importance in the planning process. Need based extension programmes are the best way to cater to farmers' needs. This can reduce the cost and wastage of resources as well. In addition, a dialogue between RRISL and RDD in the planning process is vital as both ASD and RDD are serving the same target group. This has created differential acceptance of these two groups by the smallholders as a result of poor coordination which leads to wastage of resources through duplication of some services. Hence, sound discussions between institutions at the planning are highly important to overcome such situations.

One of the major problems that exist in the present extension service rendered by RRISL is the lack of sufficient number of extension workers to cater the smallholders. An extension officer of RRISL has to provide his services for nearly 3000 farmers, which is not at all a convenient exercise, hindering the effectiveness of the extension service. Every effort should therefore be made to recruit and train additional man power and to provide them with necessary transport and other facilities which are highly inadequate at present. However, to cope up with the present situation, identification of task oriented programmes targeting a maximum number of farmers during the planning stage is essential. This will create a situation for efficient use of allocated limited resources.

Education and training of extension workers are highly inadequate and needs intensification. Also, they should have ample time to learn a technology before they can effectively teach others. If this is not realized, extension work would be like 'the blind leading a blind'. Extension workers need more training than farmers to garner credibility. Therefore, a properly planned human resource development programmes for extension officers after careful analysis of their present level of knowledge, skills and responsibilities is needed as extension is the battlefront of technology transfer. The people involved in extension must not only be technically updated but must also possess good management and interpersonal skills. With so much on their shoulders, most of them might be lacking the capability to integrate the technology developed into the farming system.

Most of the training programmes for farmers are conventional in nature. This resulted poor attraction by farmers leading to wastage of resources. Therefore, ASD has introduced effective modifications and changes in awareness raising activities. These include, *in situ* planning of training programmes through awareness and adoption tests, field demonstrations, open discussions, video documentaries on rubber cultivation and processing, mini scale exhibitions and providing opportunities to purchase essential items for rubber farming. Moreover, participation of RDD officers and private sector organizations involved in the rubber industry strengthened the dialogue between different stakeholders and the rubber farmers. The enthusiastic participation of farmers endorsed the value of these new approaches. It was highlighted by the farmers that they appreciate the presence of scientists in these forums as those are the only possible places where they can meet them.

Advisory visits by extension workers are the basic feature of technology transfer but with varying degrees of success. Hence, this was transformed into a farmer requested basis without attending on ad-hoc manner. This practice has obviously revealed some improvements. This may be further improved by sending a brief report on the visit indicating the findings and recommendations to the smallholders as a follow up action.

Encouraging and helping farmers to put up their farmers' organizations have been an effective approach towards development. With the formation of an organization, the farming community can be empowered with the knowledge and skills to identify its needs and problems, harness its resources to deal with these problems and take actions collectively. Furthermore, it is the take-off point for some of our strategies. However, this situation does not exist at a sound level in the smallholder rubber sector, as commented by the farmers themselves. Strengthening the existing farmer societies should be among the priorities in this respect. Farmers who own larger rubber estates can be considered as entrepreneurs with different economic objectives and can be regarded as a separate group in the smallholder sector. Already established Medium Scale Rubber Smallholders' Association (MeRShA) could be used as a vital strategy in technology transfer.

Farmers have a way of convincing other farmers to adopt a technology that they have successfully and profitably utilized. This is the basis for the model farmer and model farm strategy. In our experience, most rubber farmers are generally reluctant to change their farming activities as they have the 'wait-and-see' attitude. Although many farmers are very much open to new ideas and technologies, there are more farmers who would first like to see a working model before they follow the lead. To overcome this situation, model rubber farms have been established in all the rubber growing areas together with this new approach it was exercised in establishing '*Pera Gaman Rubber*

Gammana" – forward marching rubber villages - as a new concept for effective technology transfer.

For effective implementation of strategies, creation of a suitable environment and revitalizing Government policies need to be addressed. Available policies of the rubber industry have prospects and constraints. Rubber farmers gaining benefits through these policies for a long period of time have bitter experiences on receiving subsidies in the form of in-kind and cash. This hindered the expected output of the transfer of respective technologies. In order to help the poor farmers there is a need to revitalize existing policies or formalizing new policies to provide credit facilities or develop bank loan schemes.

More attention should be paid on monitoring and evaluation of activities in technology transfer programmes. For this purpose, a Management Information System (MIS) is being developed for the rubber smallholder sector. Once this is implemented, it will help to utilize and analyze the information for effective decision making and planning of extension programmes towards effective technology transfer.

Conclusion

Barriers to technology transfer are not uncommon. However, they can be successfully overcome with appropriate strategies. Appreciating farmers' ideas during the planning process, introducing novel approaches in technology transfer and helping farmers in organizing their own societies are several among them. Revitalizing the Government policies is a basic necessity for effective implementation of these strategies.

Technology Requirements and Easing Constraints in Adoption: Smallholder Perspective

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Introduction

Rubber smallholders contribute significantly to the natural rubber production in Sri Lanka. All the plantation owners who own an extent of less than 50 Acres (20 Hectares) are identified as smallholders. Although this category represents around 60% of the total extent of rubber cultivation in the country, very little attention has been given to the economic viability of smallholdings

At present, the main reason affecting the economic viability of smallholdings is the low market prices. The drop in the local RSS prices over 60% of the price prevailed a year ago badly affected the smallholders. Apart from the slump in the RSS prices in the world market due to the global economic recession, the price received by the Sri Lankan smallholder is much lower when compared with the prevailing local auction prices. The difference between the average auction price and the price received by the smallholders is in the range of Rs. 20-30 per kg (i.e. ca.20% less than the RSS 1 auction price).

The immediate impact of this crisis on the local rubber production can be elaborated as follows.

1. Smallholders having less than 2 acres of rubber have totally given up the rubber tapping and have looked for other sources of income.

2. The smallholders have been thrown from pillar to post as the latex harvesters are refusing to work for less than Rs. 350/- per day.

3. The number of latex harvesters in the country is estimated to be about 100,000, out of which 50% do not possess sufficient skill for quality tapping resulting in shortening the life cycle of the rubber tree by over 8 years.
   Use of unskilled/semiskilled latex harvesters to overcome the dearth of skilled harvesters at lesser daily wage would devastate the existing rubber cultivations.

4. The proper maintenance of the rubber plantations may be neglected by ignoring the recommendations given by RRISL.

High cost of production in the rubber smallholdings is to be dealt with prime importance for their long term survival. According to the available statistics, the cost of production (COP) of dry rubber produced in Sri Lanka is highest in Asia.
The reasons for high COP can be elaborated as follows.

1. The average number of trees per acre is around 150, though the recommendation is 200 trees per acre. In reality, out of this quantity, rated yield cannot be achieved from at least 25% of the trees available for tapping.

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2. Use of hired contract labour for all the activities in the plantation.

3. Reluctance to comply with the RRI recommended techniques available to increase the yield such as the use of rain guards, tapping before dawn using a tapping lamp, annual manuring, correct tapping techniques, etc.

4. The owner of the plantation is not residing in close proximity to the plantation. (thus the supervision of the activities in the plantation is often neglected)

5. The owner is solely depending on his supervisor's/conductor's knowledge & experience on the maintenance of rubber plantation as his level of knowledge on the plantation activities is limited

Issues to be addressed by the policy makers

(a) To improve the income status of the smallholders

1. Removal of the CESS imposed on rubber products as announced by the Government in last December.
   Though this was given wide publicity in the media, no official circular has been issued to the companies involved in the rubber industry as yet. The field latex sellers are severely affected due to this CESS collection.

2. Implementation of the subsidy of Rs. 20/- per Kg as announced by the Government. This was also given wide publicity through the media and on posters as well. However neither action plan/any procedure has been formulated nor was a scheduled date announced to implement the same.

3. Development of a formula based on the local auction prices to decide on a minimum buying price for RSS and field latex (at the village level and town level).

(b) Creating a market dictatorship for the smallholders

1. Possibility of establishing an association/organization under the supervision of the government to collect and resell RSS from smallholders. Presently the RSS buying price is decided by one or two companies who buys more than 60% of the total RSS production in Sri Lanka, irrespective of the prevailing local auction price.

2. Creating a strong body/organization for the smallholder to voice their concerns in the market, this will help to establish a sustainable economic condition for the rubber smallholder to exist.

(c) To improve productivity and bring down the cost of production on smallholder rubber plantations

1. The quality of the plants issued from the nurseries should be improved. No proper management of the nurseries can be seen at present, considering the quality and the quantity of the plants received by the smallholders through the permits.

2. The issue of permits to new and replanting applications have been limited or delayed due to unavailability of the plants at the nurseries. Due to this reason, the issue of replacement plants for the dead plants does not place

and hence, the target of having 200 plants per acre (or 500 plants per hectare) has become unrealistic.

3. Issue of new high yield clones recommended by the RRI as per their research findings, has not been implemented as yet. RRIC 121 is being issued since late 90's. Nurseries do not have even the budwood to introduce latest clones of RRISL 200 and 2000 series.

4. Proper inspection/supervision of new and replanted lands at least biannually. The present extension services seem to be not effective due to lack of coordination between the two controlling bodies. According to officials, lack of manpower also had aggravated this issue considerably towards this condition.

5. Effectiveness of the existing extension & research activities should be reviewed as transferring the research findings to the smallholder is found to be very weak. The smallholders feel that the RRI research findings mainly focus on large rubber holdings. No news bulletins or leaflets available even with the respective REOs or RDOs in area.

6. Allocate majority of funds available in the existing subsidy scheme only to the new or replanting lands of the smallholders. (i.e. less than 50 Acres) Plantation Companies, large estates and JEDB estates, who owns more than 50 acres should be capable of affording the cost of replanting through proper management policies.

7. The advises given by 03 institutions established to develop the rubber industry in Sri Lanka, namely RRI, RDD and Thurusaviya vary from each other. Instances where contradictory advises given by the 03 institutions on the same issue have been experienced. (e.g. manuring period of the year, replanting period of the year, fixing of raingurads etc.)

8. Increase the availability of the skilled Latex Harvesters and improve the skill level of Latex Harvesters in service through training programs.

9. Blocking out of large Rubber Lands should be limited to the minimum of 10 acres per block, as maintaining of rubber lands less than 10 acres would be uneconomical.
(One person can be assigned to manage a minimum of 10 acres or group farming should be introduced)

10. To have one governing body to control/administer all the issues connected to the Rubber Industry in Sri Lanka, instead of existing 03 bodies as mentioned above. This is presently functioning very satisfactorily in India, namely Rubber Board of India.

SESSION - 6

RAW RUBBER PROCESSING

Advances in Research & Development in Raw Rubber Processing Industry

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Introduction

Official launch of the Research and Development (R & D) of Natural Rubber (NR) in Sri Lanka took place 100 years ago by appointing a scientist to work on latex coagulation process. Since then, R & D work have been continuously expanded in a wide spectrum of fields including raw rubber processing. Total rubber cultivated area and thereby the annual local NR production have shown a gradual increase despite some fluctuations due to market forces. Out of the total production of 129 million kg of rubber in 2008, about 42% were in the form of Ribbed Smoked Sheets (RSS) while the balance was in the form of crepe rubber, centrifuged latex and Standard Lanka Rubber (SLR; Technically specified rubber). In the field of NR processing where field latex and field grade coagula are converted into above forms, R & D work have been carried out on process development, introduction of new chemicals and new forms of raw rubbers and development of effective effluent treatment technologies. Also, successful technology transfer mechanisms could be highlighted as the key contributors to the present status of the raw rubber processing industry. Nevertheless, R&D work should go further meeting the social, economical and environmental challenges in the present day context. This paper attempts to review the pathway of R&D for the benefit of stakeholders in the NR industry.

Achievements in the past

Process Development

Natural rubber latex which is the main raw material in the raw rubber processing industry is obtained by tapping the trees of *Hevea brasiliensis* and the yield is known as field latex. Since the quality of the field latex is not always consistent, technology plays a vital role to get a quality assured product. Similarly, raw rubber is processed by latex processors at different academic backgrounds and at different scales. Extensive training, awareness and technology transfer programmes conducted effectively over the last 100 years free of charge for the benefit of the raw rubber manufacturers have paved the way for introduction of standard natural rubber processing technologies. Sri Lanka has been able to maintain the number one position in the production of world's purest form of NR *i.e.* Crepe rubber, taking over two thirds of global market share in the crepe rubber market. In 1999, the Dartonfield crepe rubber factory of the Rubber Research Institute of Sri Lanka (RRISL) obtained ISO 9002 certification for its high quality manufacturing process and became the first government institution to own a certified factory in all types of manufacturing fields. Technical know-how and advice provided in all aspects of centrifuging of NR latex and SLR undoubtedly contributed to set up local latex centrifuging and block rubber industry.

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Introduction of New Chemicals

When the production of Tolyl mercaptan which was then used as the bleaching agent for crepe rubber was banned, an alternative chemical, water soluble xylyl mercaptan was developed for environmental safety. It prevented a possible collapse of the crepe rubber industry in Sri Lanka. An analytical titrimetric test method has also been developed to determine the concentration of active ingredient in this new bleaching agent. The development of the sole secondary preservative, tetra methyl thiuram disulphide/zinc oxide (TMTD/ZnO) which is commercially used worldwide for low Ammonia concentrated latex with the participation of a RRISL scientist is another great achievement made in the NR processing field. Papain, a locally produced substance from Papaya tree has been introduced as a natural and unique coagulant to be used in the manufacture of superior quality specialty rubber with low nitrogen content and ash content, suitable for many engineering applications which requires low heat build-up properties.

Cost Effective Effluent Treatment Technologies

In the face of growing public concern on the environmental issues, an appropriate technology to treat the rubber effluent became mandatory. RRISL was able to develop a cost effective, efficient and locally adaptable treatment technology to meet the stringent effluent quality parameters stipulated by the Central Environmental Authority (CEA) of Sri Lanka. This unique development marked a milestone in the rubber industry without which the industries would have not been able to continue under the strict enforcement of environmental regulations. This cost effective technology has now been adopted not only in the rubber industry but also in other allied industries such as coconut industries.

Improved Drying Systems

In the field of drying, forced air drying system and vacuum air drying system were developed for crepe rubber. The forced air drying system reduces the drying period by 50% compared to the conventional method of crepe rubber drying.

Recent Developments

New Forms of Natural Rubber

Crepe rubber has been solely marketed based on the traditional visual grading system irrespective of the raw rubber properties. In an attempt to discourage this grading system, technical specifications for crepe rubber were first introduced in 1994. Lankaprene with unique technical specifications was introduced with a newly introduced standard manufacturing process to the international market in 2005 as a novel marketing strategy. This is a major positive diversification of marketing of crepe rubber, deviating from the traditional visual grading system.

Material Safety Data Sheets

With the introduction of new environmental legislation particularly in European Union, raw rubber needs to be exported with Material Safety Data Sheets (MSDS). MSDS have now been prepared for all grades of raw rubbers produced in the country.

Critical Metal Ion Levels for Processing Water and Chemicals

New limits for metal ions in processing water and in bleaching agent have been proposed after conducting a series of experimental trial runs. It has been shown that maximum allowable metal ion concentration could be raised avoiding the use of very high quality chemicals thereby reducing the chemical cost.

New Drying Systems with Shorter Drying Cycles

Just before celebrating 100 years of rubber research in Sri Lanka, investigations carried out on rubber drying have revealed that drying period of any conventional grade of NR could be restricted to a single day. A new cost effective, user friendly and efficient smoking system using Single day Smoke drying units (SS drying units) which cuts down the drying period by 80% from five days to a single day was developed and introduced marking a major development in the history of sheet rubber drying. Two forms of renewable energy sources; *viz.* Bio gas and solar energy were also introduced in the new dryer. This modified drying process is being tried in large scale RSS drying systems and the results are promising. The same drying system with bio gas generated from an effluent treatment plant at a centrifuged latex factory was tried in drying of skim rubber which is conventionally dried in the form of laces in ambient air for more than one week. Field level experimental trials have confirmed that drying period of skim mat (thicker than laces) could be reduced to 20 hours cutting down the prolonged drying period and excessive space requirement. In addition, since this process does not require the conversion of skim rubber mats into laces for drying, a remarkable saving on electricity could also be achieved offering advantages in two forms. Uninterrupted drying process introduced in conventional crepe rubber drying towers has also shown that complete dryness of crepe laces could be achieved within a single day.

Future Challenges in NR Processing

There are number of equally important aspects which need attention of scientists and raw rubber processors in order to meet the possible future challenges in the raw rubber processing sector. These challenges could be basically categorized as;:

1. Challenges to be met associated with the worker shortage
2. Challenges in the competitive market scenario with increasing quality demands

Ways and means to overcome these challenges are,

Handling worker shortage :

This can be effectively done by Mechanization of crepe rubber manufacturing process through;

(a) development of auto coagulum feeding system to the macerator,
(b) introduction of mechanical agitation system to replace manual fractionation process,
(c) designing and development of a rubber creping battery, and
(d) introduction of conveyor belt system to transport rubber within the NR processing factory

Further, the socio-economic reasons for the reluctance of the youth in involvement of the rubber industry should be identified and practical solutions need to be found and implemented.

Competitive market scenario

The following are suggested to meet the challenges.

Introduction of a set of standard and simple utensils particularly to the smallholder sector to determine the dry rubber content in the field latex. This will help them to add the correct amounts water and chemicals in order minimize the quality variations of raw rubber or centrifuged latex produced to ensure good quality.

Product development/diversification to meet customer requirement and/or to increase value addition at the raw rubber processing factories through market intelligence and technological research.

Investigations towards development of novel varieties of raw rubbers through nano technology.

Cut down the manufacture cost through various means such as introduction of environmental friendly, energy efficient renewable alternatives and efficient energy utilizing practices

Use of chemicals which warrant environment safety in raw rubber manufacture

Research and development work will continuously be carried out in collaboration with the stakeholders and national universities, despite the heavy financial constraints experienced by the institute and with the limited number of trained scientists remaining in the country.

Technological Advances Needed in Raw Rubber Processing with Emphasis on Cost, Quality and Environmental Issues

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Introduction
Rubber processing needs consideration under the following three specific areas; *viz.* quality, cost and environmental issues. Quality aspects should commence from latex collection stage to the end products of raw rubber processing.

Latex Collection in the Field
Research should provide more guidelines in terms of cleanliness in latex collection from the tree until it is received in the factory for processing. This is a very important area which usually tends to receive low priority.

Performance of Raw Rubber Processing
There are numerous applications for natural rubber across the world. The unique combination of properties found in Natural Rubber (NR) cannot be fully duplicated synthetically. Rubber is a collective term for macromolecular substances of natural origin. This is a valuable hydro carbon.

NR primarily comprises of polyisoprene. The latex has approximately the following composition:

Constituents	Percentage
Water	55-70
Rubber	30-40
Resins	1.5-2
Protein	1.5-3
Ash	0.5-1
Sugar	1-2

The latex, which is rich in rubber, can be processed preserved in the form of centrifuged latex, crepe rubber, sole crepe, Ribbed Smoked Sheets (RSS) and Technically Specified Rubber (TSR) etc. The more commonly used practice is straining the latex and coagulating the standardised latex with the use of an acid. Coagulation separates the raw natural rubber from the water, forming a solid mass (coagulum) that is then further processed.

Crepe
Pale crepe rubber is among the highest quality crepes. Production of this high-quality natural rubber is achieved with sodium hydrogen sulphite ($NaHSO_3$), formic acid and using of bleaching agent (tolyl mercaptan) which is followed by milling process for further purification and washing the residuals. This process requires excessive quantities of pure water. The rubber is then converted into thin laces for drying. The rubber is dried

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within 2-3 days at a temperature of 37° C in a drying chamber for packing and preserving. This product is marketed as thick or thin pale crepe under different grades on the appearance and colour.

Sheets

Sheet rubber comes in two different forms and they are named as;

ADS (Air Dried Sheets)

RSS (Ribbed Smoked Sheets)

The differences between these two products are the drying method and the colour of the sheets. Since coagulation and milling are simple processes than that of crepe, the purity in this rubber is lesser.

Technically specified natural rubber (TSR) - Standard rubber

This grade of rubber is not a common grade in Sri Lanka.

Centrifuged Latex

The process involves preserving of latex is preserved by introducing ammonia, TMTD, lauric acid etc and then removing of available water naturally present in latex through centrifuging.

New technologies need to be adopted in RSS, crepe and centrifuge latex production in Sri Lanka since these three grades are the major product mix of NR that consumes higher volumes of water and the discharge accounts for the highest pollution of water in Sri Lanka.

Negative factors

Crepe rubber is still graded visually and this visual colour varies from clone to clone and also seasonally within a clone. Therefore making a homogeneous product through out the year in a plantation is a difficult task. Since the rubber is used for technical products the visual grading will not serve the end users requirement fully and the constraints faced by the manufacturer will be lesser, if product marketing is done on an analytical report that indicates the properties.

Proposed improvements to Manufacturing Techniques of Crepe rubber

The present cumbersome and time consuming crepe rubber manufacturing process needs a dramatic change for cost and processing time reduction. The scientists have to look for improvements in the present manufacturing process. The industry will benefit if a direct succession type of process is developed with the following features.

1. The coagulum to be sheared to granules and fed to the initial mill through a conveyer (better washing with limited amount of water)
2. The existing 02 roller mills to be replaced with batteries of mills that will consist of two sets of horizontal grooved mills, followed by a Diamond and a Spiral mill and thereafter 02 smooth rollers which will complete the entire process of milling without any manual feeding or any labour inputs, in a shorter time period.
3. The milled laces to be coiled at the point of the output from the smooth mill and then be spun at a very high revolution to remove the surface water and pass through a conveyer type drying chamber to dry artificially with high air flow to extract the humid air, which will not change the colour of the crepe rubber produced.

Minimize water usage (environment conservation and resource management)
Water plays a major role in achieving the visual grading colour in the product. Finding the required amount of quality water is a difficult task faced by the plantations. Water is becoming a scarce commodity day by day. The natural latex itself consists of 55 - 70% pure water. In addition to this, an additional volume of pure water is added to standardize the rubber bringing the rubber content in latex to 10%. This is achieved by adding a high volume of water at the first stage of the process and this is continued with further washing and in milling, using additional volumes of water. Finally, to process 3 parts of latex 97 parts of water (volume wise) is added.

This water is discharged to the natural environment untreated or partially treated creating an environmental issue and affecting the natural aqua life and making unsuitable for human consumption.

If this volume of water could be reduced in the process of natural rubber manufacture or improvements are brought about to recycle the water discharged from the factory back into the process, it will lead to preservation the most precious resource of the earth. Therefore, the industry would like the scientists to look into the possibilities of processing NR to crepe by using least amount of water and also to look into the possibilities of making use of the water that comes with latex for the same. This will reduce a considerable volume of water that is now drawn from natural ground resources. At present, the discharge of water after treatment carries a Chemical Oxygen Demand (COD) level of 60 mg/l max and a Biological Oxygen Demand (BOD) level of 400 mg/l max which is neither fit for human consumption nor use in other hygienic purposes.

Test Reports
The next requirement is to look at the possibility to manufacture rubber that could be marketed with a test report, deviating from the ancient visual grading. To do this, the scientists need to produce guidelines that could be easily understood by common rubber buyers, exporters and the consumers. This could create a demand to replace the visual grading system, with a test report that will serve the end users better. History has proven that similar reports have replaced the visual grading and a good example is the Standard Malaysian Rubber (SAR) now marketed using a test report which has received international recognition for marketing this grade of rubber.

Cost control
If scientific breakthrough is achieved to reduce the water usage in the process of NR it will definitely cut down the number of millings, and chemical use which will reduce the cost of chemicals, energy and manpower. This will enable Sri Lankan rubber to be offered to the world market at competitive prices whilst maintaining the niche marketing edge which is being enjoyed by the Sri Lankan rubbers for many years with technical specification.

CDM and Carbon Trading
Natural rubber is now widely accepted as an important tree species that can sequester significant amounts of CO_2 from the atmosphere. Rubber has a distinct advantage, as it has an additional Carbon sink in the form of rubber (isoprene) produced in the laticiferous system in addition to the bio mass.

The annual average production of rubber per tree over a 25 year period is around 0.16 tons. The amount of carbon produced per tree in this way is expected to be 0.14 tons based on the assumption that 88% of carbon in basic isoprene unit. The total amount of rubber produced per hectare is expected to be around 43 tons, which means 37 tons is in the form of carbon which is equivalent to 135 tons marketable CO_2.

Therefore can the scientist device some system of pooling this CO_2 for seeking carbon credits under a rubber CDM project. Can we negotiate with the consumers of our rubber for such credits?

Quality Consistency in Raw Rubber

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Introduction

Natural rubber (NR) latex, a milky fluid obtained by tapping the bark of *Hevea brasiliensis* tree, is processed into raw rubber from which rubber products are made. NR latex is usually converted into raw rubber. Generally, there are two major types of raw rubber: centrifuged latex and dry rubber forms. Centrifuged latex (CL) is the starting raw material for any NR latex based products such as gloves, condoms, balloons, catheters, baby soothers and latex foam. On the other hand, dry rubber forms such as Latex Crepe, Ribbed Smoked Sheets (RSS) and Technically Specified Rubber (TSR) are the main raw materials for any dry rubber based products like tyres, tubings, hoses, footwear and automotive components etc.

Sri Lanka produces all four major types of raw rubber. According to raw rubber production statistics, total raw rubber production was about 129,000 metric tons in the year 2008 and the raw rubber production showed steady increase during the last five years. Sheet rubber (RSS) is mainly produced by smallholder sector whilst latex crepe and centrifuged latex are mainly produced by either plantation or private companies at large factories.

Maintaining quality consistency in raw rubber is vital since raw rubber is the main raw material for the production of dry rubber based and latex based products. Some of these products require high standards of quality as they are used in health care industry. For example, latex crepe rubber is generally being used to produce pharmaceutical products such as pharmaceutical and surgical appliances whilst centrifuged latex is generally used to produce examination and surgical gloves and condoms. Maintaining the quality of raw rubber is, therefore, very important to achieve the required quality and standards of the final rubber products.

This paper reviews that how main steps in raw rubber processing can be handled/ controlled to improve and to maintain the quality consistency of raw rubber. In addition, this paper discusses the new techniques and methodologies developed and future research and development needed in raw rubber manufacturing processes in view of improving and maintaining the quality of raw rubber.

Present methodologies to maintain the quality consistency of raw rubber

In general, raw rubber (i.e. latex crepe, RSS and centrifuged latex) manufacturing process can be divided into the following main steps: collection and preservation of latex, processing of latex (coagulation and milling for latex crepe and RSS, centrifuging process for centrifuged latex), drying of laces/sheets, sorting and packing of finished products

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Collection and preservation

Collection of good quality field latex is vital to produce centrifuged latex and dry rubber forms, particularly latex crepe. Therefore, collection of field latex should be carried out under carefully controlled and hygienic conditions in order to produce high quality raw rubber. It is important to preserve NR latex until it is processed since NR latex tends to coagulate within a few hours after tapping due to bacteria acting on non-rubber substances.

The first important step in manufacturing good quality CL is the proper preservation of NR field latex at the field and in the factory. Proper preservation of latex by incorporating preservatives with recommended dosages at appropriate time is vital when making centrifuged latex. The most common method of preserving NR latex is incorporating ammonia with secondary preservatives such as tetramethylthiuram disuphide (TMTD) and zinc oxide (ZnO). It is important to add the recommended dosages of those preservatives at the correct time and, more importantly, maintain the required level of those preservatives in the latex until it is processed.

Processing of latex

Crepe rubber is the purest form of natural rubber and Sri Lanka has a reputation of being the supplier of the world's best quality crepe rubber to the export market. Hence, each step in latex processing (i.e. bulking and standardisation, addition of sodium bisulphite, fractionation, bleaching, coagulation and milling) should be carried out strictly in recommended procedures in order to produce good quality crepe rubber. For example, fractionation and addition of bleaching agent should be carried out effectively in order to improve the colour of the crepe rubber. Use of inferior quality water in standardization process results either discoloured or inferior quality crepe rubber.

Drying

Drying is another main step, especially for crepe rubber and sheet rubber, in raw rubber manufacturing process to maintain the quality of rubber. Generally, crepe rubber drying is carried out with warm air in a drying tower operated at 34 ^{0}C for three days. It is advisable to use the recommended/standard drying method to achieve uniform drying of laces and to produce crepe rubber without any discolouration.

New developments to maintain the quality consistency of raw rubber

Crepe rubber

Manufacture of latex crepe rubber requires good quality water and different chemicals. There is a possibility of contaminating the crepe rubber with heavy metal ions (i.e. iron, copper and manganese) due to the use of inferior quality water and chemicals and, as a result, quality of the crepe rubber can be affected. According to the findings of recent research carried out at RRI, maximum level of metal ions that can be present in processing water and in crepe rubber without affecting the quality of crepe rubber are introduced.

Although, latex crepe rubber has superior properties, it has not been presented to the end user with technical specifications and, as a result, the superior quality of this crepe rubber is not recognized. Producing Lankaprene grade of crepe rubber, which is produced by strictly adopting standard manufacturing process and graded according to the technical specifications, would be beneficial to maintain the quality consistency of this grade of rubber.

Ribbed smoked sheet (RSS)

Very recently developed "Single Day Smoke drying unit" (SS drying unit) can be used to achieve uniform drying of sheet rubber and, as a result, quality of RSS can be improved.

Centrifuged latex (CL)

The most critical quality parameter in both field latex and centrifuged latex is the Volatile Fatty Acid number (VFA No.). CL is not accepted by the product manufacturers if the VFA number is above 0.05 in most cases. Due to the bad state of preservation, VFA number of CL sometimes increases up to the levels unacceptable to product manufacturers. Recent research carried out has shown that high VFA latex (up to 0.1) could be blended with low VFA latex (up to 0.03) at a ratio of 20: 80.

Research and development needs to improve the quality of raw rubber

With the present situation in rubber industry, it is important to improve the quality of raw rubber through research and development and thereby producing good quality raw material for local rubber industry and increasing the export earning of raw rubber. RRI has initiated following research work to develop new methodologies/techniques to improve the quality of raw rubber.

Application of nanotechnology

Nanotechnology is to discover novel behaviours and properties of materials with dimensions at the nano scale, which ranges from 1-100 nanometres (nm), and controlling and manipulating the nano scale materials into useful products/structures. At nano scale, materials behave quite differently compared to those at larger scale. Simply the materials, at nano scale, can show different properties which have not shown at larger scale. Therefore studies are focused to introduce this novel technology into raw rubber in view of improving the quality of raw rubber.

Presently most of the estates use thermoplastic cups for the collection of field latex. Development of new latex collecting cup with a nano-structured surface which provides a zero adhesion of latex into the latex collecting cup and with antibacterial properties would be a definite advantage to improve the quality of NR field latex.
Preservation of field latex is another area where nanotechnology can be applied successfully. Application of preservatives (i.e. ZnO and TMTD) at nano scale into the field latex would enhance the effectiveness of the preservative system.

Development of a new latex collecting vessel

Designing of a new latex collecting vessel with multi functions has been initiated in order to improve the quality of field latex and to make easy of latex handling procedures at the field.

Mechanization of crepe rubber manufacturing process

RRI is in the process of developing methodologies to mechanize the crepe rubber manufacturing process in order to enhance the efficiency of manufacturing process as well as to maintain the quality consistency of the crepe rubber.

SESSION - 7

PRODUCT MANUFACTURE & TECHNOLOGY

Research and Development towards Sustainable Development of Rubber Products Industry

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Introduction

The rubber industry in Sri Lanka is one of the five largest Gross Value Addition (GVA) sub sectors and it is a typical resource-based industry backed by high quality Natural Rubber (NR) produced in the country. Manufacture of rubber products began in Sri Lanka way back in 1936 with the establishment of a tyre retreading plant in Colombo by Richard Peiris & Company, followed by another tyre retreading Company in the year 1948 by Associated Motorways (AMW) Ltd. This paper attempts to compile a concise description of the gradual development of the rubber industry in Sri Lanka and its present status, RRISL leadership in Research and Development activities for the advancement of the rubber industry in the country and important scientific achievements made by the scientists of the RRISL.

Growth of the rubber products industry

The expansion of the rubber product manufacturing sector in Sri Lanka began somewhere in early 1980s and was slow at first, but gathered momentum in the early 1990s. The successful growth of the industry can be partly attributed to the liberalization of the trade and investment in Sri Lanka, which began in 1977. Very attractive incentives have been offered to potential investors in export oriented projects. In 1997, in order to promote the sector, the rubber based product manufacturing sector was named as a "Thrust Industry" by the Sri Lankan government and thereby new investments in this sector qualified for special incentives. Most of these large scale industries are either direct foreign investments or joint ventures with local partners.

Rubber sector per capita income is estimated at US$ 2350, which is quite significant in comparison to other sectors. Compounded annual growth rate (CGAR) of the rubber sector has remarkably increased in the recent past and it showed an increase of 9.8% between the period 1995 and 2005, 23% between 2001-2005 and it was 47% during the period 2004-2005. Total export earnings from the raw rubber and rubber product sectors in the year 2008 is recorded as Rs. 67 billion, where tyre sector, other rubber product and glove sectors being the major contributors amounting to 34.2, 7.3 and 11.1 billion rupees, respectively.

Types of rubber products

At present a wide variety of rubber products are manufactured by the rubber product manufacturing sector. Moulded and extruded products such as solid and pneumatic tyres, inner tubes, rubber belts and a wide variety of automotive components, agricultural and other hoses, industrial floorings, mats and shoe soles are major dry rubber based products manufactured by the Sri Lankan industry.

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Latex product industry has expanded significantly over the last decade and presently it attributes to around 27% of the local production of NR. Surgical, household, agricultural and examination gloves, foam rubber mattresses, cushions and pillows, toy balloons, Halloween masks and rubber toys are among the major products manufactured by the latex product industries in Sri Lanka.

Contribution to Research and Development (R&D) by RRISL

The Rubber Research Institute has played a vital role in the development of both dry rubber and latex industries in the country since its inception in 1909. Research and Development on NR based products and human resource development are two major areas of work that the RRISL has been involved over these years. It is to be noted that the efforts of RRISL scientists have contributed immensely towards numerous developments in the rubber industry particularly in areas such as customer compounding, latex and dry rubber blends, latex prevulcanization and modified forms of Radiation Vulcanization of Natural Rubber Latex (RVNRL). As such, different segments of rubber industry such as rubberized-coir, NR foam, molded and extruded products, latex dipped and cast products industries are benefited by the tailor made R&D work of RRISL. Further, RRISL is instrumental in maintaining the quality standards of the finished products cost effectively to compete in the world market.

Among some of the major developments by RRISL in the recent past were, developments of latex blends of NR and synthetic lattices for property enhancement, variety of NR/Synthetic Rubber (SR) blend compounds mainly for tyre components and automobile parts developed in collaboration with the rubber based companies, developments of examination gloves using RVNRL in the year 2001 complying to globally accepted American Society for Testing and Materials (ASTM) specifications, development of novel techniques to reduce the extractable protein levels of NR latex based gloves as a solution to latex allergy issues of NR based gloves, improvements in quality and storage stability of prevulcanized lattices and development of a highly effective room temperature curing system for the latex based products industry which is now being adopted by the Small and Medium Entrepreneur (SME) sector.

Rubberized-coir (RC) based product industry has been one of the oldest industries in the country. Mattresses and various articles used in the horticultural sector such as biodegradable mats and pots are the main products manufactured out of RC. RC based weed control mats used as a ground cover are among the cost effective developments of RRISL.

A permeable hose (soaker tube) based on polyethylene powder and rubber crumb composite which is highly suitable for irrigating plantation crops during droughts was developed by extrusion-sintering process and commercialized in collaboration with DSI Company. High impact material based on NR/thermoplastic blend compounds (TPNR) developed by RRISL have been commercially used in the production of coagulating pans and tapping cups in the country and quite popular among the plantation companies in view of maintaining quality of NR latex.

The expansion of the foam rubber industry in Sri Lanka started with the establishment of few large companies during the past few years. Production of special types of foam needed by foreign buyers such as extra soft foam and memory foam by Richard Peiris & Company Ltd., accounts for the major breakthrough of the foam rubber industry in Sri

Lanka. Research work carried out by RRISL connected towards perfection of the production of foam contributed to these industries immensely. Some of the foam rubber products developed by the Rubber Technology & Development Department include, shoe components, carpet backings, textile coatings, soft foam, masks and a novel specimen for a space movie.

RRISL has played a significant role in the pollution control research work as well. Discovery of a highly effective microbiological treatment technique had been fully responsible in eradicating severe environmental pollution created by the untreated factory effluent discharge by the raw rubber processing factories in the country. The process has been widely acclaimed as an innovative sustainable development in the field and has won several international and national awards.

Services by RRISL to the stakeholders

RRISL provides a wide range of testing services to the industry. These services include chemical, water and wastewater testing, physical property analysis of dry rubber and latex compounds and their products, raw rubber and latex properties and identification and characterization of polymer products.

Research and Development Needs in the Dry Rubber Based Product Industry

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Introduction

Rubber products form an important category of items, which are essential for day to day life, and this will continue to be so for many decades. The contribution of Research and Development (R & D) has been the major factor for the development of the rubber product industry to its current status. However, it can be said that the quantum of recent advances in this field is minimal, and several major issues remain to be addressed in the current perspective.

Many chemical and technological advances have been made since the discovery of vulcanization by Goodyear, which could be considered as the most important single event, which contributed to the rubber product manufacture. Since then, new materials, equipment, processes, products etc. have appeared which are responsible for the current developed state in this industry. Most of the important discoveries, which have been actually accepted and used by the industry, happened during the middle part of last century. During this period, there was very large number of active researchers at higher educational establishments and more importantly at R&D departments of prominent polymer and rubber chemical manufacturers. Today, one finds that comparatively much less R&D work is done, especially by chemical manufacturers, and as a result very limited fundamental improvements are being made towards the development of the rubber industry.

Research & Development needs

New materials

The materials used in the rubber industry have not changed significantly for many decades. The same or very similar materials are being used by industry today as it did, a long time ago. Polymers, fillers, curing agents, accelerators, scorch inhibitors, anti-degradants, etc. which are used by the industry are the same which were introduced and used many years ago. Although it is true that the above materials have satisfied the needs of the industry fairly well, new and better performing materials would be welcome by the industry for further progress to be made.

Replacement of some materials used by industry due to environmental and related concerns is also a current topic, which deserves attention of R&D workers. Although some alternatives are introduced, it appears that they are not so satisfactory when performance is concerned.

Energy consumption

Rubber product manufacturing industry is a high energy consumer up to the vulcanization step where a material with poor thermal conductivity has to be dealt with. Large amount

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of energy is needed in mixing of compounds dealing with high viscous polymers and materials, which do not disperse easily. This is an area where the industry is expecting significant contributions in the form of R&D inputs.

Testing methods
Issues such as, instability of properties of rubber products due to storage hardening effects, blooming phenomena in manufacturing and during end-use and recycling of end-of-life rubber products need better test methods to predict service performance of rubber products. The industry is not satisfied with available know-how and new solutions are eagerly awaited.

Machinery and Equipment
As a positive development, the machinery & equipment manufacturers are satisfactorily engaged in providing new advances to the rubber product industry, in order to maximize productivity and also to eliminate variation from the production processes.

Research and Development Needs in the Latex Based Product Industry

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Introduction

Production of natural rubber in 2008 in Sri Lanka was 129,000 metric tons and approximately 35,000 metric tons of this amount was centrifuged latex. About 70% of the centrifuged latex was consumed by the glove industry. Other smaller scale industries of significance include latex foam products, mattresses, balloons and rubberized coir. Common to all the latex based industries, whatever the product manufactured, is the need for collection of good quality field latex and its conversion into centrifuged latex. The centrifuged latex is compounded with chemicals and then processed into products of different shapes and sizes for various applications.

In the case of gloves, the purpose of wearing a glove is to protect the wearer against hazards like abrasion, cut from sharp objects, puncture by sharp objects, contact with gases, chemicals, solvents and micro- organisms. Basically the glove functions as a barrier between the skin and the hazards of the environment. Another aspect is to protect objects handled from contamination by the "handler" especially in cases of food and electronic components. The required performance parameters are normally achieved by judicious manipulation of the formulation ingredients, latex type (Natural Rubber (NR), synthetic and blends) and in the case of fabric supported gloves by use of liners which may be composed of engineering yarns such as Kevlar.

Whatever the glove type the customer looks for the following: *viz.* adequate protection, comfort, dexterity, non allergenicity and value for money. Hence this paper reveals research and development needs of latex based product industry.

Research and development needs to suit future needs

With respect to gloves, in recent years the focus from customers has been the need for enhanced–technical performance at the lowest price possible. In the present world-economic climate the market has become that of buyers and to remain in business, manufactures have the difficult task of reducing prices whilst maintaining / improving performance. Further, new legislation has been introduced in the form of Registration, Evaluation and Authorizing of Chemicals (REACH) and other legislature which limits / prohibits use of certain chemicals in formulations. To meet these new challenges the latex industry needs solutions for the following strategies.

Reduction of energy costs

The energy component in latex product manufacturing is substantial and hence the research and development effort should concentrate on, energy conservation and use of alternative energy sources. The main energy consuming area in manufacture of latex

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products is in heating of leach water and ovens. In the ovens the energy is utilised in evaporation of water from the coagulated latex film and for the vulcanisation. In terms of technical input in conservation of energy, it is necessary to develop low temperature cure formulations which do not add significantly to the chemical cost but require less energy to cure. Development of pre-vulcanised latex which does not require high energy consumption in its manufacture is also an option.

Low cost formulations
Means of reducing the cost of formulations without compromising performance and other properties such as weight of product also needs to be explored. Aspects such as structure property relationships of fillers and minimising settling of fillers need to be studied. In this context the use of sub-micron fillers offers a potential.

Maturation of latex
The maturation time before centrifuged latex can be used to manufacture articles is typically 3 weeks. It is known that during these three weeks natural higher fatty acid soaps in the latex increase (due to the main hydrolysis of lipids) which confers colloidal stability to the latex against mechanical shear and makes the latex processible. An understanding of a means of accelerating this hydrolysis process would enable the latex to be used earlier than 3 weeks and thereby help to reduce stocks and costs.

Factors affecting cut, puncture, tear and abrasion properties
Cut, puncture, tear and abrasion resistance properties are features required in most gloves. An understanding of the factors affecting these properties in particular; influences in respect of structure property relationships and blends of NR with synthetic lattices are very much needed.

Use of nano materials in the formulations could also offer new routes to improve performance and properties. Such routes need to be explored as they potentially offer large property enhancements. As such, development of low cost nano materials e.g. zincs oxide, accelerators, sulphur and fillers need to be explored.

Similarly for fabric supported gloves, development of low cost yarns having high performance based on indigenous plants in Sri Lanka need to be studied, for instance, in China use of bamboo yarns confer to the fabric special properties which are not shown by synthetic fibres. Such research could open up new industrial avenues in Sri Lanka as well.

Factors affecting chemical permeation
Resistance to chemicals is another feature which is also required in many products especially in those meant for industrial applications and even food related applications. A study of factors affecting chemical permeation and a means of improving it is desired. Aspects we need information include impact of

- altering formulation ingredients
- use of blends of polar and non polar elastomers / polymers and /or graft copolymers
- application of thin coatings on the rubber surface
- use of nano materials in the formulation/surface or in combination with coatings

Formulations to meet new restrictions of chemicals
Development of novel formulations is desired to meet newly introduced standards where for certain applications, traditional formulations relying on conventional accelerators are not permissible. For instance, in the food industry in Germany, restrictions in respect of limits to (2-Mercapto Benzothiazole) MBT in the gloves makes it impossible to use of (Zinc Mercapto Benzathaiazole (ZMBT) in the vulcanisation formulation. Further, new restrictions to the use of chemicals in the form of REACH regulations are being introduced as Substances of Very High Concern (SVHC). At the moment the list has 15 chemicals and is reviewed every year. It is quite possible that in the near future certain rubber chemicals could be included in this list. Therefore, an urgent requirement is to anticipate these chemicals and develop alternate formulations without them.

Development of very-low / zero protein latex
Methodologies for achieving zero-protein NR latex needs to be developed. Use of proteolytic enzymes offers an opportunity. Other routes include exploring the use of fillers such as aluminium salts, fumed silica which bind the extractable proteins in the rubber matrix. Further, preventing their elution need to be explored. In the market already there are NR products having Extractable Protein (EP) content as low as 1 microgram per gram rubber. Further, measurement of EP to low levels needs to be developed. Conventional methods based on the modified Lowry method are not sufficiently sensitive since a minute amount of allergenic substance can trigger adverse reactions in patients. Hence, new techniques based on High Performance Liquid Chromatography (HPLC) need to be employed. Further, test facilities ought to be developed and made available.

Effluent disposal
Waste water effluents from the Latex industry contain nitrates, nitrites, calcium salts, soaps, ionic and non-ionic surfactants, non-rubber substances, ammonia, sulphur, zinc salts, cotton /other textile fibres and residual accelerators or chemicals. Improvement of disposal methods of such effluent ought to be addressed.

Developments of Dry Rubber and Latex Blends for Rubber Based Products

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Production of a new material by blending elastomers is cheaper than developing new monomers which require novel polymerization processes. The use of rubber blends is almost as old as the synthetic rubber industry, which began prior to the second world war and generally originates from desire to combine technical or economic features of two elastomers.

The development of new rubber blend systems and the usage of these blends in various applications have increased remarkably during the last decade. The reason for this is for many applications, single rubbers provide inadequate performance. By proper selection and mixing of the component rubbers, the desired properties of individual elastomers could be combined.

Blends of rubbers can be prepared by a variety of methods and out of these methods mechanical blending and blending of elastomers in the latex stage are the most widely practiced procedures.

A mixture of two rubbers is said to be compatible on a molecular, scale, only if mutual solution takes place during mixing and the resultant blend constitutes a thermodynamically stable single – phase system at room temperature. The majority of elastomer blends consists of two phase systems. In a two phase system, the discrete phase is dispersed in the continuous phase or the two phases exist as co-continuous. Truly miscible rubber blends are rare and it is not a requirement for most applications Homogeneity at a fairly fine level is needed for optimum performance, but some degree of microheterogenity is required to preserve the individual properties of the respective elastomer components. Incompatibility between dissimilar rubbers may occur due to difference in viscosities, thermodynamic incompatibility and difference in cure rate. Compatibility of a rubber blend may be characterized by the solubility parameters of the individual elastomers, thermodynamics, glass transition temperature of the blend and microscopy.

Properties of a rubber blend depend mainly on choice of elastomers, blend ratio, compatibility of the polymers, phase morphology and the technique used to produce the blend and these factors are themselves interdependent. Distribution of compounding ingredients especially reinforcing fillers, also has a great effect on the properties of elastomer blends.

Mixing of elastomers and compatibility began to be of scientific and technological interest with the arrival of synthetic rubbers. The early work on blends of natural rubber (NR) with styrene – butadiene rubber (SBR) was the beginning of an approach to

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elastomer blends. The use of blends of NR with general purpose synthetic rubbers mainly SBR and polybutadiene rubber (BR) is common in the industry, especially in tyre building. The other synthetic rubbers named as speciality synthetic rubbers, consumed by the Sri Lankan rubber products manufacturing industry are polychloroprene rubber (CR), acrylonitrile-butadiene rubber (nitrile rubber or NBR), ethylene – propylene – diene rubber (EPDM) and isobutylene – isoprene rubber (butyl rubber or IIR).

Our main achievements in the export industry are in tyres, gloves, flooring and engineering components such as seals, gaskets and other mouldings. Blends of NR with synthetic rubbers (SRs) are used in the manufacture of these products to combine mechanical properties of the component rubbers or for a cost reduction..

NR has an outstanding combination of strength and resilience qualities. Also it has excellent resistance to chipping, cutting and tearing, high abrasion resistance, but poor in heat and weather resistance, compression set, non–polar oil and hydrocarbon solvent resistance and fire resistance. It has always been of great importance for producing truck tyres due to its low heat build–up. Incorporation of SBR and BR into tyre tread compounds enhances abrasion resistance. Resilience is improved and heat build–up is reduced by the incorporation of BR. However, the percentage of BR in NR/SBR/BR tri-blend compounds should be kept at a low level as high amounts of BR tend to cause processing difficulties. Further, incorporation of SBR improves resistance to flex–cracking, whereas presence of NR in this tri–blend system imparts cut growth and tear resistance.

Sri Lanka is the leading producer of solid tyres. These are bulky rubber products and due to poor thermal conductivity, heat dissipation is slow. In this regard, compounds based on NR are the most suitable although some SR can be used. A solid tyre manufactured with NR will always have a cooler running temperature in comparisons to a tyre made with SR. Thus the presence of NR in the blend contributes to high resilience, low heat build–up and rolling resistance, while SR mainly SBR improves the wear characteristics of the compounds as stated earlier.

Blends of NR with speciality SR which combines the excellent qualities of NR with the special properties of the synthetic component have gained considerable importance in the field of rubber technology. NBR combines excellent resistance to non–polar oils and fuels both at normal and elevated temperatures. Therefore, combination of excellent strength properties with excellent resistance to non–polar oils and fuels is expected from blends of NR and NBR. Applications of this blend system include seals, rings, industrial and household gloves.

A combination of strength properties and non–polar oil resistance / fire resistance could be achieved by blending NR with CR. Weather resistance, especially resistance to ozone could be combined with strength and other excellent qualities of NR by blending NR with EPDM. Resistance to air permeability which is required for products such as inner tubes combined with the above mentioned properties of NR is expected from blends of NR with IIR.

In addition to dry rubber based blends of natural and synthetic rubbers, blends of rubber lattices are used in the industry for manufacture of latex based products such as gloves, foam products, etc. NR latex is used in the manufacture of products requiring high strength and low modulus, where resistance to hydrocarbon solvents, light and ozone is not a prime consideration. SR lattices are mainly used where special resistance properties such as good heat ageing, resistance to ozone, hydrocarbon solvents, non-polar oils and flame are needed. Synthetic rubber lattices are mainly produced by emulsion polymerization of monomers and lattices of SBR, NBR and CR were the first to develop through this technique. NBR latex is used for hydrocarbon solvent and non-polar oil resistance applications and CR latex is used for flame retardant, adhesive as well as solvent and oil resistant applications. By blending different types of synthetic lattices (polar / non-polar rubbers) with each other or in combination with NR latex, gloves with a combination of properties such as cut, strength, puncture, solvent permeability, heat and oil resistance could be developed.

NR/SR blend compounds developed by the RRISL during the last decade at the request of the rubber product manufacturing industry include; NR/SBR/BR tri-blends for tyre treads, NR/reclaimed rubber blends and NR/SBR/reclaimed rubber tri-blends for tyre retreads, NR/NBR blends for engineering applications, e.g. hydraulic brake parts and for dolly wheels, NR/IIR blends for tyre inner tubes, ENR/NBR blends for engineering applications, NR/CR blends for engineering applications and rice-huller rollers, NR/EPDM blends with good mechanical properties and ozone resistance for weather resistant applications, NR/EPDM blends for engineering applications such as lip type rubber rings and accumulator diaphragms and for tyre curing bags, NR/NBR latex blends for industrial / household gloves, NR/CR latex blends with good strength and non-polar oil resistant properties for household / industrial gloves as well as for manufacture of flame resistant foam and NR/SBR latex blends for foam masks and carpet foam underlays. In addition, NR/synthetic polymer latex based blends such as NR/polyvinyl acetate (PVAc) blends with high strength and ageing properties suitable for manufacture of products requiring a combination of these two properties and NR/PVAc latex foam for fabric coatings are some of the other developments of the RRISL on latex blends.