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IRRIGATION SYSTEMS FOR RUBBER NURSERIES

S A Nakandala, K D N Weerasinghe, P Seneviratne, S M M Iqbal and P D Pathirana

INTRODUCTION

Irrigation and water management are two major concerns in rubber nursery management, especially when rubber cultivation is moving towards non-traditional areas in the Intermediate and Dry Zones of the country. The annual plant material requirement for replanting and new planting programmes of the country is about three million. Accordingly, large scale rubber nurseries should be established in non-traditional areas too with proper irrigation scheduling in order to ensure high quality plants and high productivity in nurseries.

Until the recent past, many nursery owners used rubber hose or water delivery pipes with a water pump to irrigate their nurseries and that can be categorized as a type of border irrigation. However, there is no proper irrigation schedule for this type of irrigation system and it mainly depends on time. Therefore, nursery owners should schedule their irrigation programme pre-dawn for each day to minimize losses due to wind and evaporation. However, in general, irrigation goes on from morning up to mid-day (10-11 a.m.) due to large extent to be covered. In addition to the time, high labour input and irregularities in irrigations (over and under irrigation) have shown negative consequences on the efficiency and the productivity of nursery management.

Recent advances in irrigation technology

Irrigation technology has developed rapidly from border to micro irrigation and from manual to automation, over the last two decades. With that, RRISL has introduced sprinkler systems like micro irrigation systems for large scale rubber nurseries (Nakandala *et al.*, 2008). Introduction of sprinkler irrigation system as a modern irrigation technology is very important for improving productivity in large scale rubber nurseries. Sprinklers are becoming more popular among nursery producers where labour shortage prevails and water scarcity occurs, especially in non-traditional areas. The advantage of moving towards sprinkler irrigation systems not only saves water but also increases the quality of planting materials due to the improvement of crop micro climate and reduces the labor engagement in watering.

Sprinkler irrigation systems for rubber nurseries

Sprinkler irrigation system sprays water into the air and allows falling on to the ground, resembling rain, it cools the leaves and reduces the midday closure of stomata. With proper designing of piping layout, sprinklers can cover a large area overlapping about 50 - 100 per cent depending on the requirement. Sprinkler irrigation can be used for almost all crops and most soil types. However, it is not suitable for fine textured soils due to poor infiltration rate. Land leveling is not essential for irrigation with sprinklers. Labour costs are usually less than for surface irrigation methods on soils having a high infiltration rate and on steep and rolling land (Michael, 1978).

Wind distorts sprinkler patterns and causes uneven distribution of water. The water should be clean and free from sand, debris and less in dissolved salts. The sprinkler method usually requires the highest initial investment as compared to surface irrigation methods. Power requirement is usually high since sprinklers operate with a water pressure of 0.5 to more than 10 kg/cm^2. Fine textured soils with a slow infiltration rate and windy areas cannot be irrigated efficiently with sprinklers (Michael, 1978).

A study was conducted to evaluate the two types of sprinkler systems *i.e.;* technically specified and non-specified sprinkler systems over manual watering for rubber nurseries in the Intermediate zone of Sri Lanka in the year 2013 (Nakandala *et al.,* 2014). Non-technical and technical sprinkler systems are having their own advantages and disadvantages according to their system design (Fig.1). A technical or impact sprinkler operates with a revolving type sprinkler head with two nozzles. Non-technical sprinklers are low cost and designed with an orifice that is not technically specified.

(a) Non – technical sprinkler

(b) Technical sprinkler

Fig. 1. Types of sprinkler nozzles

The operational characteristics such as uniformity co-efficient, pattern efficiency and discharge rate were used to access the performance of the sprinkler irrigation systems. To evaluate the systems on operational characteristics, a bucket experiment was designed to test the water distribution pattern of each system. A 6 m × 6 m square was marked on the field and it was divided in to 36 squares which have 1 m^2. The sprinkler was centralized on the 6 m × 6 m square and 36 buckets were placed centrally on each square. The sprinkler was operated and water was collected in the buckets for half an hour. The collected water was measured in millimeters separately (Michael, 1978). Based on the bucket experiment uniformity coefficient, pattern efficiency was calculated as follows.

Uniformity co-efficient (Cu) is a measurable index of the degree of uniformity obtainable for any size of sprinkler, operating under given conditions.

$$\text{Cu} = 100\left(1 - \frac{\Sigma x}{mn}\right)$$

In which

x = Numerical deviation of individual observations from the average application rate (mm)

m = Average value of all observation (average application rate) (mm)

n = total no of observation points

A higher uniformity coefficient was obtained by technical sprinklers (92%), when compared to non-technical sprinklers (85%).

Pattern efficiency representing the performance of the sprinkler system was determined by gauge records of the bucket experiment as the ratio of average minimum depth of catch and average depth of catch obtained from the above (Michael, 1978). It was found that the average pattern efficiencies of the two types of sprinklers were 87% and 86% respectively which was satisfactory. However, high wind velocity and the changes of wind direction distorted the pattern efficiency of the system and uniformity of distribution of water (Nakandala *et al.*, 2014).

The discharge rate of each type of sprinkler varies with nozzle type, pressure and area of the orifice of the sprinkler nozzle. The results of morphological and physiological characters of plant growth showed that both types of sprinkler irrigation systems have performed well over manual watering. The cost should be considered when selecting a suitable type of sprinkler system for a nursery. High initial investment is required to install a system with pumping and filtration units. The cost of technical sprinkler system is high due to its design technology compared to non-technical sprinklers. However, the design should be done considering many factors such as water availability, power source, area to be covered, *etc*. other than the cost factor in order to optimize its use. The operational cost for the system varies with the size of the nursery, the stage of the crop stage and capacity of the water pumps, *etc.*

Salicylic acid application for rubber nurseries

A number of studies are being conducted by RRISL to minimize the effect of drought stress by using salicylic acid (SA) while reducing the irrigation water requirement. SA is a naturally occurring plant growth hormone, which has the ability to withstand environmental stresses by activating defense mechanisms and adjusting their cellular metabolism in many plants species.

Chemically, salicylic acid is a monohydroxybenzoic acid, a type of phenolic acid and a beta hydroxy acid. It has the formula of C_6H_4 (OH) COOH, where the OH group is ortho to the carboxyl group and is also known as 2-hydroxybenzoic acid. Salicylic acid has a molar mass of 138.12. It is an odorless and colourless crystalline compound (Fig. 2).

Fig. 2. Salicylic acid crystals under room temperature

Salicylic acid induces systemic acquired resistance against plant pathogens. Therefore, exogenous application of salicylic acid modulates intra cellular antioxidant enzymes inducing peroxidase, superoxide dismutase and increases plant tolerance to biotic and abiotic stresses (Habibi, 2012 and Senaratna *et al*., 2000).

As Salicylic acid is known to play an important role in abiotic stress tolerance, considerable attention has been focused on the use of Salicylic acid in irrigation scheduling. Therefore, RRISL conducted trials to explore the possibility of using Salicylic acid with irrigation for rubber nursery plants in order to reduce the water requirement of plants under drought conditions in the Intermediate zone of Sri Lanka.

Salicylic acid is a monohydroxybenzoic acid, a type of phenolic acid and a beta hydroxy acid. It has the formula of C_6H_4(OH)COOH, where the OH group is ortho to the carboxyl group and is also known as 2-hydroxybenzoic acid. Salicylic Acid has molar mass of 138.12 $g{\cdot}mol^{-1}$. It is an odorless and colorless crystalline compound (Fig. 2). This colorless crystalline organic acid is widely used in organic synthesis and functions as a plant hormone.

This study revealed that the application of Salicylic acid as a soil drench at a concentration of 0.5 mM helps to elevate plant growth under drought stress conditions, while reducing the net irrigation requirement of rubber nursery plants by 25 per cent (Nakandala *et al*., 2012).

Drip irrigation system for rubber nurseries

The drip irrigation system is another type of micro irrigation method which is becoming increasingly popular in areas where water scarcity is a major problem. Several studies have been conducted based on drip irrigation system for rubber nurseries especially in the Intermediate Zone, as a novel technique for water saving irrigation methods (Fig. 3).

Fig. 3. Drip irrigation system installed in a rubber nursery

The drip system comprises emitters or drippers at selected spacing for supplying water approaching the consumptive use of the plants while minimizing deep percolation, runoff and soil water evaporation. In drip irrigation systems, 90% application efficiency can be achieved than other systems (Michael, 1978). A substantial amount of water saving can be achieved from drip systems when compared to sprinklers or any other surface irrigation method. Drip irrigation permits the application of fertilizers through the system which is an advantage to address rubber nurseries for the labor shortage.

Disadvantages of the drip system include high initial cost, individual emitter requirement per plant, need of filtering requirement, clogging of emitters and poor water distribution efficiency. Experiments are being carried out to see the suitability of installing drip irrigation systems with alternative power sources such as solar power for rubber nurseries in the Intermediate Zone of Sri Lanka.

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EFFECTIVE USE OF GASEOUS STIMULATION SYSTEMS IN SRI LANKAN RUBBER PLANTATIONS

K V V S Kudaligama and V H L Rodrigo

INTRODUCTION

Original use of ethylene gas in rubber was reported in Malaysia in early 1960s (Taysum, 1961). Nevertheless, the inconvenience in handling the gas, limited its application. Instead of ethephon, direct use of ethylene came back to the industry as a method of efficient utilization in high panels and also to address the labour shortage in tapping. Puncture tapping was initially tried with ethylene [*e.g.* Hypodermic Latex Extraction (HLE)] but failing that, mini cuts (4 cm) were introduced. The Rubber Research Institute of Malaysia made some modifications to the ethylene based gaseous stimulation and introduced a system called 'REACTORRIM' with a smaller size jacket coupled with a buffer tank for ethylene gas. Another system was also introduced as 'RRIMFLOW' in 1990 (Said and Ramlan, 2006). Considering the difficulties in fixing the jacket, another gaseous stimulation system with sticker type jacket named Patch n' Tap was also introduced. This had two inherent problems – to wit- water trapped in the jacket could not be removed and the gas penetration to the tree was weaker in some cases. Later, an improved version of this system, G-Flex, has been introduced facilitating to remove the water trapped inside the jacket. In Sri Lanka, RRIMFLOW and G-Flex systems were popular among growers (Fig.1) and used by some RPCs and smallholders. From time to time accessories of these systems have come to the local market through various private companies and growers tend to use these systems mostly in older fields.

a.

b.

Fig. 1. A tree with **a**. RRIMFLOW and **b**. with G-Flex harvesting systems

Observations

Latex yield

In general, out of two gaseous systems tested (*i.e.* RRIMFLOW and G-Flex), RRIMFLOW system showed better performance with both stimulation frequencies tested. In the same estates, ethephon stimulated CUT (control upward tapping) was able to provide *ca*. 7.6 kg of yield per tree per year (YPT). The potential annual yield per hectare (YPH) (for 100 days of tapping per tree) with 15 days gassing intervals were a little higher than the 30 days interval in both harvesting systems (Table 1). Yields given by G-Flex system were lesser than that of ethephon stimulated CUT under both stimulation frequencies. During 1st three months, the yield of gaseous stimulation systems was considerably high and thereafter, yields tended to decrease. Dry rubber content (DRC) of latex was partially less during 1st three months of stimulation (Table 1). On average, the productivity level of RRIMFLOW system with 15 days and 30 days stimulation frequencies were 4880 and 4000 kg/ha/yr, respectively whilst it was 2800 and 2200 kg/ha/yr with G-Flex system. However, with ethephon based CUT system, average productivity was about 3000 kg/ha/yr. At any condition, the average DRC did not fall below 34%.

Table 1. *Comparison of different Control Upward Tapping (CUT) systems in terms of mean % dry rubber content (%DRC) in latex, yield per tree per tapping (GTT) and potential yield per tree per year (YPT) and potential yield per hectare per year (average of three years). Ethephon stimulated CUT system is shown as CUT-ET. (Tapping days = 100, and stand per hectare = 400 trees)*

Stimulation frequency	Estate Clone YOP	Tapping system	%DRC 1st 3 months	%DRC After 3 months	GTT (g) 1st 3 months	GTT (g) After 3 months	Potential YPT (kg)	Potential YPH (kg/ha/yr.)
15 days	Dartonfield RRIC 121 1986	RRIMFLOW	35	36	127	82	8.2	3280
		G-Flex	34	35	110	68	6.8	2720
	Udapola RRIC 100 1989	RRIMFLOW	34	36	138	122	12.2	4880
		G-Flex	34	34	76	72	7.2	2880
30 days	Dartonfield RRIC 121 1986	RRIMFLOW	36	37	100	75	7.5	3000
		G-Flex	33	37	86	55	5.5	2200
		CUT-ET	36	36	83	76	7.6	3040
	Udapola RRIC 100 1989	RRIMFLOW	35	38	132	100	10.0	4000
		G-Flex	36	37	59	55	5.5	2200
		CUT-ET	37	38	81	74	7.4	2960

Limitations

Bark wounds with oozing latex and rotted bark were reported initially in fields stimulated with ethylene gas at 10 – 15 day intervals with borer attacks to the wood in some fields (Plate 2). If wounds occur they could be treated with the fungicide Ridomyl followed by candasan as a dressing. This was due to the high dose of ethylene hence should be completely controlled with the calibration of nozzle to 15 ml ethylene per shot with 15 and 30 days gassing interval.

The number of trees affected with TPD showed a slight increase over time. Nevertheless, affected trees have increased by 5% on average, and it is acceptable as the fields are on the verge of uprooting.

a **b**

Fig. 2. a) Bark wounds and **b)** latex oozing in trees with high frequency gassing

Leaking jackets appeared to be one of the biggest problems with gaseous stimulation systems. Rain water collected in jackets was also leading to bark rot in some instances. Leaking jackets should be checked and repaired prior to gassing. There was an abnormal growth in the bark at the place where the jacket was fixed and hence in changing the panel after a year, jackets could not be fixed at the recommended place. In most cases, jackets were fixed above the expected length of the new tapping panel.

Correct way of adopting gaseous stimulation on upper panels

Despite the recommendations made by the manufacturers to inject ethylene every 12 days, research carried out studies in Sri Lanka on the RRIMFLOW and G-Flex have shown the ideal/sustainable gassing frequency as once a month under Sri

Lankan condition. Ethylene gas and accessories need to be imported from Malaysia hence cost is high.

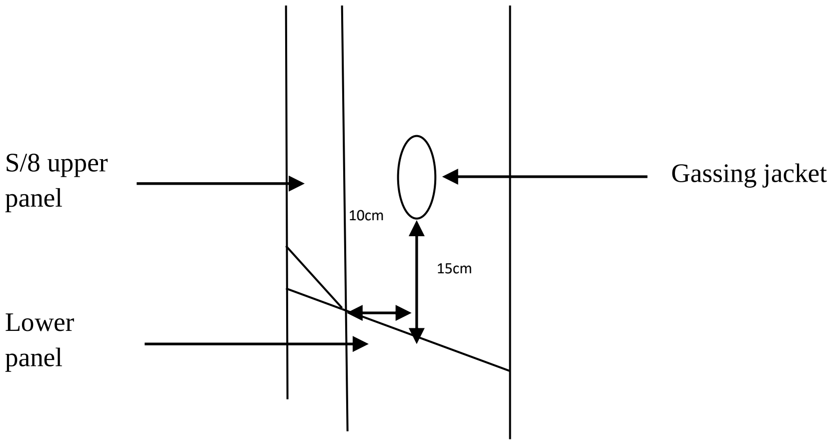

Fig. 3. Proper way of fixing the jackets for ethylene stimulation

Recommended protocol for gaseous stimulation in Sri Lanka

- Suitable as a method of control upward tapping (CUT) with an upward S/8 (one eighth) cut.
- Adopt only after usage of C (BI-1) panel as a part of intensification plan.
- Panel should be changed to the right hand side. It is suitable to change the panel on a yearly basis leaving about 25cm height for annual bark consumption. Start above the "poi kanu" of panel D (BI-11) (Fig. 1).
- Gassing jacket should be properly fixed to the tree without any leaks.
- Adjust the regulator of the gas cylinder to release 15ml of gas per shot prior to gassing.
- Before each gassing, check the jackets for leakages and seal, if necessary. Remove if any water filled inside jackets.
- Gassing at 30 days intervals may result in less harm to the tree bark sustaining the yield. Stimulation and tapping should not be done on the same day.
- Tapping should be done at d3 (once in three days) or d4 (once in four days) frequency.
- Tapping should be done as much as early and late collection should be done to collect the maximum latex yield.
- Instead of coconut shells, larger (about 1L) cups are suitable for latex collection.
- Do not stimulate if tapping cannot be done due to rain or any other circumstances.
- Use rainguards to maximize the yield.

- Do not allow to retain rain water inside the leaking jackets as it may harm the bark of the tree.
- Do not stimulate if the latex dry rubber content (DRC) fell below 30%.
- Do not keep the jacket in the same place for more than 1 year.
- Do not allow double tapping. Recovery tapping could be done.
- If bark abnormalities (wounds, latex oozing from back cracks or wood borer attacks) occur, stop gassing and allow the tree to rest. Clean the affected area and apply a suitable fungicide/insecticide. Use a water resist dressing such as candasan during wet weather.

Financial status of gaseous stimulation based low intensity harvesting systems for upper panels

For fixing jackets and gassing, cost per tree to the present market price is about Rs.500/= per tree per year. This is totally an additional cost for tapping and it needs to harvest about 2 kg of additional amount of rubber (@ Rs.300/= NSA) per tree per year to cover the cost. During first 4-6 months, average intake per harvester (from 300 trees) varies about 30-45 kg per day and thereafter this trend gradually decreased reaching about 15-35 kg per day. Under general circumstances, harvesters' daily income increases accordingly to the additional quantity of latex brought. However, especially during the initial four tappings after gassing dripping time prolongs and late collection is necessary to maximize the profitability. At very low rubber prices, gaseous stimulation systems are not financially viable to the growers.

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RECENTLY INTRODUCED LOW INTENSITY HARVESTING SYSTEMS INCREASE THE PROFITABILITY OF RUBBER PLANTATION INDUSTRY

K V V S Kudaligama and V H L Rodrigo

INTRODUCTION

Harvesting latex is considered to be the most costly operation contributing to over 1/3 of the cost of production particularly in commercial plantations. It requires a greater level of skill and this together with poor wage structure has led to the shortage of skilled harvesters. In particular, % daily out turn of harvesters appeared to be *ca.* 12% hence the fields allocated to absentees are either left without being tapped regularly or tapped by unskilled workers damaging to long-term yield potential of the rubber trees. Generally, 37% of harvesters employed in the plantation sector are not skilled enough.

Traditionally, rubber tree is tapped along the half of the circumference of the trunk (S/2) with the frequency of once in two days (d2); hence each harvester is given two tapping blocks. Removal of skill factor with mechanizes tapping has not been successful and not cost effective in instances where it has been tried, hence low intensity harvesting systems (LIH) have become a practical agronomic tool to address these issues in latex harvesting

In LIH, there are three options, *i.e*. either by reducing the frequency of harvesting, or tapping cut length or both. In general, more emphasis has been given to the first option in base panel harvesting. To compensate for yield loss due to lowering the intensity, trees are being stimulated with ethephon. Concentrations and application frequency of ethephon were changed only to achieve comparable yields to the traditional S/2 d2 harvesting system. In addition to the yield levels, effects on plant growth, bark consumption in tapping and its development, tree health, latex physiological parameters and raw rubber properties were have been concerned when developing these new LIH systems together with financial analyses. Response of different clones to low frequency harvesting systems differs and would depend on the climate also.

Benefits of adopting low intensity harvesting systems

The time gap between two tappings is extended by a few more days in low frequency harvesting (LFH), therefore each harvester can be allocated to a greater number of tapping blocks resulting in reduced harvester requirement. Even with the reduction of tapping cut length, the number of trees allocated to each tapping block could be increased and the time period of harvesting on virgin bark could also be increased. Application of ethephon may increase the yield per tree per tapping increases resulting enhanced daily intake of harvester and therefore, there is an option to increase their wages. Furthermore, the overall increase in harvesters' productivity results in reduction of cost of production. With less number of tapping days per year rate of bark consumption is reduced and economic life of the tree increases providing an additional benefit to the growers. Further, any delay in replanting in LIH delays the investment required for the same and the cost of immature upkeep. Then, the estate will have more revenue (income generating) area with LIH as the proportion of mature extent increases against the immature. Therefore, overall profitability of the estate will further increase. Environmentally, delay in replanting with extended lifespan reduce soil erosion for a unit time. Further, it facilitates to fix more atmospheric CO_2 for an extended period contributing to mitigate climate change.

Recently two new extended LIH systems 1) reduce the harvesting frequency beyond the presently recommended once in three days and 2) reduce the tapping cut length from half spiral was recommended to.

Newly recommended low intensity harvesting systems

- S/2 d4 system (tapping a half spiral cut once in four days frequency) with monthly application of 2.5% ethephon except during wintering.

- S/4 d3 system (harvesting a quarter spiral cut once in three days frequency) with application of 2.5% ethephon twice a month except during wintering.

Instead of two tapping blocks to a harvester in the traditional S/2 d2 system, three tapping blocks can be allocated to a harvester in S/4 d3 and four tapping blocks in S/2 d4 system. Therefore, labour use in latex harvesting is reduced by 33% and 50%, respectively. In general, latex harvesting requires 0.7 workers per hectare under the traditional way of tapping. This worker requirement is reduced up to 0.4 in S/4 d3 and 0.3 in S/2 d4 systems (Fig. 1). The total cost of stimulant (@ Rs.1200.00 per kg of 5% ethephon) per hectare per year in S/2 d4 and S/4 d3 harvesting systems is Rs.3840.00 and Rs.4608.00, respectively whilst application cost per hectare per year (@ Rs.500.00 cash name for applying 300 trees) is Rs.6667.00 and Rs.16000.00. Even though with this additional cost, profitability of both LIH systems is greater due to the reduction of labour use in latex harvesting and increasing the worker use efficiency. Therefore, S/2 d4 and S/4 d3 reduce the harvesting cost by 23.9% and 22.1% hence overall cost of production by 8% and 7%, respectively under hired labour condition. Profitability is about three times higher if own labour is used for harvesting. The respective increase in the net income appears to be Rs.48,000/= and Rs.36,000/= per hectare per annum.

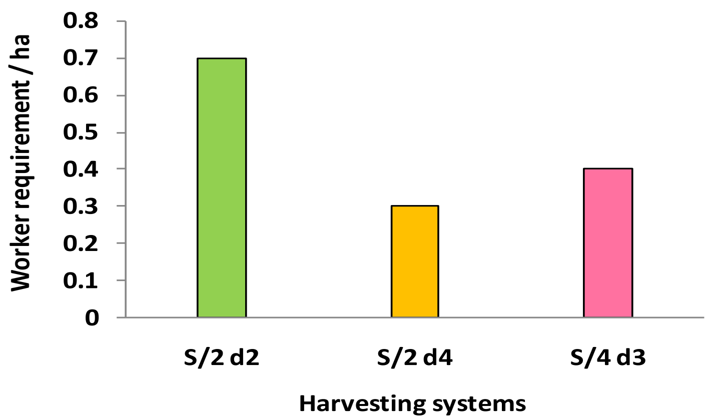

Fig. 1. Worker requirement can be reduced with new harvesting systems

With a greater amount of latex harvested each day, newly developed LIH systems provide an opportunity to have improved wages for harvesters. Under general circumstances, harvesters' daily income increased by 36% (about Rs.1300.00) in S/2 d4 system and 17% (about Rs.1150.00) in S/4 d3 system (Fig. 2). With higher labour use efficiency, the LIH systems are rather insensitive to any further labour wage increase. Therefore, their potential use in the future would be very high.

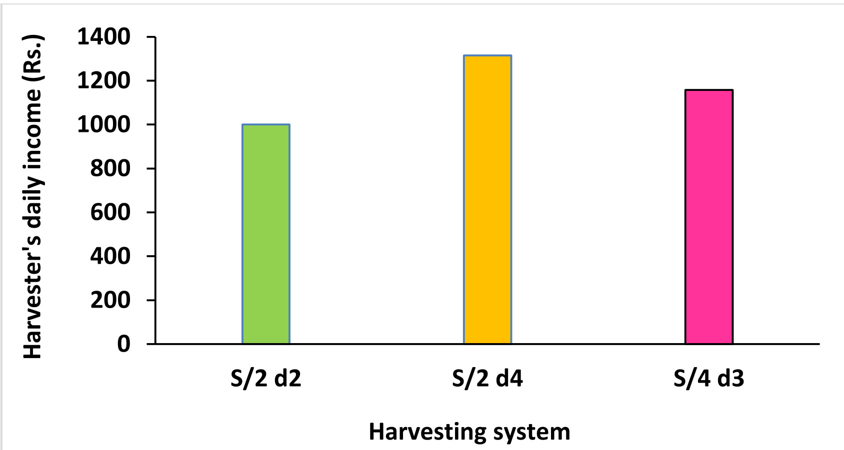

Fig. 2. Harvester's income increases with new low intensity tapping systems

Because of the lesser bark consumed, base panels are allowed to tap for 48 years in S/2 d4 and for 54 years in S/4 d3 system. This will have a positive impact on both overall economics of an estate and the environment. Potential increase of the tree lifespan will increase the long term profitability of rubber cultivation as shown in Table 1. Also, it addresses the issue of existing high level of bark consumption in rubber estates. If an estate is not interested in increasing the lifespan of rubber, the management will have an option to employ semi-skilled workers.

Table 1. *New harvesting systems secure long term financial benefits to the growers*

Scenarios	Harvesting system	Net present value (NPV Rs. at 10% discount rate)	Internal rate of return (IRR %)	Benefit cost ratio (BCR)
With standard lifespan	S/2 d2 (30yrs)	372,373	12	0.80
	S/2 d4 (30yrs)	683,375	13	1.18
	S/4 d3 (30yrs)	570,119	12	1.14
With potential lifespan	S/2 d4 (48yrs)	859,355	13	1.21
	S/4 d3 (54yrs)	774,286	13	1.18

New LIH systems will increase the profit margin in rubber estates by reducing the cost of production. Further, any delay in replanting in LIH delays the investment required for the same and the cost of immature upkeep. Then, the estate will have more revenue (income generating) area with LIH as the proportion of mature extent increases against the immature. Therefore, overall profitability of the estate will further increase.

If an estate is not interested in increasing the lifespan of rubber, the management will have an option to employ semi-skilled workers for latex harvesting as high level of bark consumption is not a big issue in the LIH systems developed. Particularly in S/4 d3 system, the presently used 30- year lifespan could be completed only with the tapping on the virgin bark. If no consideration is given to the renewed bark, then the skill of controlling the tapping depth in virgin bark would not be a big issue.

On average at present, the bark consumption rate in tapping in rubber estates is 67% higher than the expected rate resulting in shortening of tree lifespan. This can be corrected with the new LIH systems.

Workers in the plantation sector are considered to be in one of the underprivileged communities in society. Income disparity widens this gap. With the LIH systems developed, their wages could be enhanced hence a change in their livelihood and improved social dignity are expected.

Environmentally, delay in replanting in LIH means less soil erosion for a unit time. Further, it facilitates to fix more atmospheric CO_2 for an extended period contributing to mitigate climate change.

Correct adaptation of low intensity harvesting systems on base panels

- Use a stencil for marking the panel (S/2 d4 - approx. 4” per year and S/4 d3 – approx. 5.5” per year).

- Use the following stimulation protocol for clones assigned to tap at S/2 d2 frequency (except RRISL 203 and clones assigned to tap at d3 frequency)
  - S/2 d4 system - 2.5% ethephon, monthly for (10 rounds per year)
  - S/4 d3 system - 2.5% ethephon, once in two weeks for (24 rounds per year)
- Avoid stimulation during refoliation period. (Preferably end of February and end of March rounds)
- During 1st three years (Panel BO-I, 1st-3rd year), apply as a 1cm width band above the tapping cut using a ¼" brush after tightening bristles leaving 1.5cm from the edge (approx. amount per tree is 0.6 g for S/2 and 0.3g for S/4 cuts)
- From 4th year to end of A panel (Panel BO-I, 4th - 12th year) apply as a 1.5 cm width band along the tapping cut using a ½" paint brush after tightening bristles leaving 1.5 cm from the edge (approx. amount per tree is 1g for S/2 and 0.5 for S/4 cut)
- From B panel onwards (Panel BO-II onwards) apply as a 2.5 cm width band along the tapping cut using ¼" paint brush after removing about 1cm of bristles from the edge (approx. amount per tree is 1.6 g for S/2 and 0.8 for S/4 cut)
- Strictly adhere to the correct intensity of tapping
  - S/2 d4 system : 7-8 tappings/month
  - S/4 d3 system : 10 tappings/month
- Never do double tapping
- Recovery tapping can be practiced immediately after the due date for tapping or before as a proactive measure maintaining the maximum possible days of gap between any tapping.
- If you are using oil based ethephon necessary dilutions could not be done by using water. Therefore, 2.5% ready mixed ethephon should be bought directly.
- Best time to start stimulation is at the last week of April with the new green canopy.
- Avoid stimulation during severe droughts or if tapping has to be suspended for a long period during heavy rainy periods
- Tapping and stimulation should not be done on the same day
- Do not stimulate if latex dry rubber content is reduced below 30%. Stimulation could be continued after recovery.
- Do a late collection or delay the collecting time during the initial three tappings after stimulation.
- Proper rainguarding will maximize the benefits

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STRAREGIES TO MAINTAIN THE RECOMMENDED STAND IN RUBBER CLEARINGS TO IMPROVE PRODUCTIVITY

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INTRODUCTION

The average rubber productivity in Sri Lanka remains below 1000 kg/ha/year despite the fact that 75% of the clones planted in the country possess a potential yield over 2500 kg/ha/year.

When analyzing the contributory factors for the low productivity, the most decisive factor is the poor stand/ha in the field. The number of trees recommended to grow in one hectare of land get revised from time to time. Long term economic analysis of data from some long term density trials reveals that the ideal recommendation on the tree per hectare should be made for different clones separately. However, at present, the stand per hectare is the same for all recommended clones and 516-519 trees are recommended under three different spacing systems. Generally, at planting the full stand is planted but the extra 10% plants provided are not utilized properly. The old practice was to maintain them near the boundary in a row buried in a deep drain where the growth is highly restricted. Even after a year, the girth remains less than half the expected growth of 10 cm girth. The choice of the spacing system is partly to change the position of planting holes in a replanting field but it is mainly to suit the terrain; on flat terrain square planting is ideal, if intercropping is not practiced. However, it is always advisable to go for intercropping as land productivity is increased, extra income is generated during immature phase with annual crops and throughout if long term perennial crops are used and more than that, when intercrops are planted, generally farmers presence in the field is maximum. The rubber plants are also looked after when they come to look after the intercrops. The intercrops are fertilized frequently, no weed growth due to inter row space is occupied by the intercrops and also weeds within intercrops are anyway controlled for the growth of intercrops.

In hilly terrain, the farmer has little choice on special arrangements. He has to go for avenue planting or contour planting. Rubber planted in double row spacing has two systems for spacing of rubber rows; 2.7 x 2.7 m which allows 70% of rubber and 3 x 3 m allowing 63% of rubber. These spacing systems are adopted mainly for cinnamon and tea with rubber. But small lands less than one acre or so is not suitable for these double row systems as after leaving at least 2.5 m from the fence, the number of double rows that can be accommodated is very low, depending on the shape of the land. The number of trees that can be planted in one hectare of land under three different spacing systems are given in Table 1.

Table 1. *The number of rubber plants that can be accommodated in one hectare of land under different spacing systems*

	Recommended spacing system	Stand
1	4.3 m x 4.5 m square planting for flat land without intercropping	516
2	3.5 m x 5.5 m -Avenue planting method I.	519
3	2.5 m x 7.75 m - Avenue planting method II (ideal for intercropping and for hilly terrains)	516
4	2.7 m x 2.7 m double rows x 18 m	361 (70%)
5	3 x 3 m double rows x 18 m	325(63%)
6	2.4 m x 12 m single rows	361(70%)

Minimizing the loss of plants due to white root diseases

Generally, at replanting the planting holes are marked avoiding earlier planting holes as a precaution to avoid White Root Disease (WRD) contacts from previous infected roots. However, if the previous plantation has White Root Diseased patches it is compulsory to mark the diseased patch of the old stand, before uprooting the trees of the old stand. The recommendation is to white wash the naturally available rocks to mark the boundaries and if not available, to bury sizable stones and white wash them. If this most important step is neglected, it is not practically possible to maintain the new plantation healthy and the symptoms of the diseases will appear only after the second or the third year. Once the area is marked, the recommended practice is to uproot the trees in the infected area, if trees are available, along with two rows adjoining that area with utmost care under strict supervision. The recommendation is to uproot the entire root system if possible with the use of a monkey grubber which allows the majority of the root system pulled out. If backhoe machines are used, strict guidelines should be given to them to keep the roots of the infected trees in the original place without moving around and roots up to a size of a pencil should be uprooted and burnt in situ. If this step is avoided at planting it cannot be done once the new plantation is established (Advisory Leaflet - 2016/07 - Field Establishment and Immature upkeep). In Sri Lanka, as per the last survey results, about 5-10% of the rubber plantations are reported to have been infected with White root disease reported by the Plant Pathology and Microbiology Department. This is one of the reasons for poor stands in rubber estates which has a direct impact on productivity. In Sri Lanka, the average production of rubber fields is anyway 10% lower due to White Root Disease. Therefore, if replanting is done without adopting the recommended pre-planting practices and land preparation methods, trees in the former WRD patches start to show symptoms after about 3 years such as yellowing and bucking of leaves. As the disease becomes severe, flowering and fructification are also seen. By this time root systems are spread around and treatments need a lot of effort and are very costly. Therefore, with marginal rubber prices and low productivity levels farmers or planters pay the least attention to attend to control the disease. Sometimes, the farmers are unaware that WRD is deadly and have no knowledge of the recommendations that they should follow at planting.

Accordingly, the first and most important practice to be adopted to maintain the recommended full stand throughout is to adhere to recommendations on preventing White Root Diseases occurring in the fields and if it occurs to adopt proper chemical treatment methods to control it.

Vacancies and the presence of runts

The presence of a large number of runts and vacancies is the other reason for a poor stand/ha. Therefore an important practice to adopt is filling vacancies during the first three years of the establishment of the plantation. In order to achieve this, a new recommendation was issued by the Plant Science Department of RRISL in 2012 (Advisory Circular 2016/07). That is to grow the 10% extra plants issued at planting in the same field along with the rest of the plants, to be used for filling vacancies when the need arises.

Diagram 1 illustrates the planting points of the 10% extra plants in a field. The maximum period that extra plants can be allowed in the field is 2 ½ - 3 years.

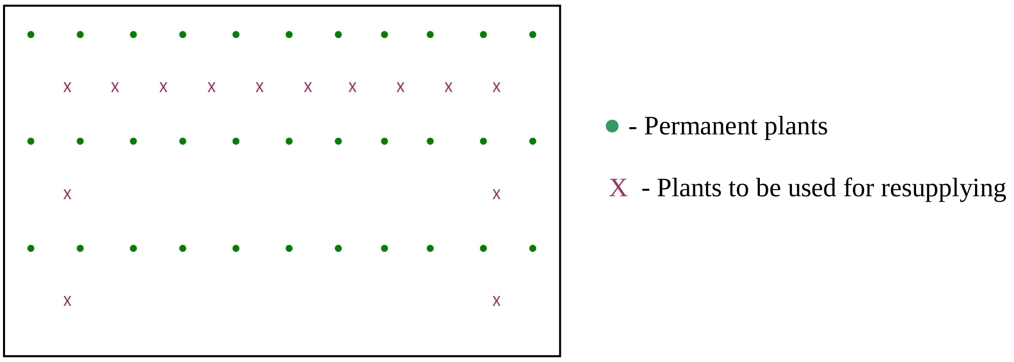

Diagram 1. The recommended arrangement of the planting points of the 10% extra plants in a field up to a period of 2½ - 3 years

Depending on the shape of the rubber land, extra plants can be accommodated along the boundaries may vary, but the extra plants must be removed at the end of 2½ years, before they start to compete with surrounding plants due to high density for light and nutrients.

The plant re-supplying schedule is given in Table 2. If field establishment is done in the South West Monsoon (SW), season, then the first supply of plants should be in the following North East (NE) Season in the same year. Similarly, as given in Table 2, if planting was done in the North East Monsoon Season this year, the first re-supplying should be done during the South West Monsoon of the following year.

Table 2. *Round of plant supply, season of the plant supply, age of the clearing at each supply and plant type or how they should be introduced to the new place of the field*

Round of refilling	Season of the supply	Age of the clearing	Form of the plants
1st	SW following year	6 months	3-4 whorls plants
2nd	NE same year	1 year	5-6 whorls plants
3rd	SW 2nd year	1½ years	Stumped buddings should be prepared with the plants prior to moving.
4th	NE 2nd year	2 years	
5th	SW 3rd year	2½ years	

It is very important to highlight that, no extra plants planted in between permanent planting rows are allowed to remain in the field after the fifth consecutive supply or in other words after when the clearing is 2½ years old. By this time, the tree girth should be about 25 cm and they start competing with the permanent plants affecting the growth or the girth of the plants.

The first round of refilling is done after 5-6 months of planting and plants used here will have 3-4 leaf whorls. It is very important that planting as well as filling vacant positions should be done with the onset of monsoon rains. Normally rainy season lasts for about 2-3 months and the plants introduced at the beginning of the rainy period have ample time to get established in the new place with new roots. Even if the root system is damaged, plants having leaves can soon develop new roots due to the root- inducing hormones namely auxins produced in the aerial parts of the plant get transported down to induce roots. Similarly, as new roots develop they produce plant hormones, namely cytokines which supports and trigger shoot growth of the plants. Accordingly, when a plant starts growing with new flushes of leaves that indicate it is established in the new place with new roots developed in it.

The second supply is generally done after one year of the field establishment of the clearing. Therefore, trees will have 5-6 leaf whorls. It is extremely important that transplanting of larger plants should be done with utmost care. The time of planting, i.e. to start the procedure at the beginning of the rainy period is the most important factor to be considered.

The second important factor is the maturity stage of the top whorl of leaves of supplying plants, when polybag plants of advanced state of growth are used. It should be in the stationary phase of growth. As the growth of rubber trees occurs in flushes. This type of growth is known as episodic growth. The rubber trees should not be moved around if they have elongating shoots or tender leaves of the top whorl. At any of these growth stages, if the root hairs get damaged or broken, the tender leaves and the shoot may get affected leading to die- back. Any such die- back condition can be stopped by cutting the affected position of the shoot a few inches below the lower part of necrosis.

However, though it is not recommended as a general rule, if a plant that is to be moved to another place has 5-6 leaf whorls, the leaves of the lower 2-3 whorls can be cut at the petioles and removed in order to minimize the transpiration. This will be useful if a dry spell occurs soon after replanting.

From the third round of supply onwards, the plants cannot be just pulled out and planted in the vacant planting hole. In order to transplant a large size plant “stumped budding” technique should be used. The main steps of the preparation and transferring of the plant are shown in Figure 1.

Step I	**Step II**	**Step III**	**Step IV**
At the beginning of the monsoon	**2 weeks after**	**2-3 weeks after**	**After about another 2-3 weeks time**
Exposing the tap-root and pruning at 2’ below ground level.	Pollarding the main stem at 8’ and applying lime.	Bud bursting stage; ideal for uprooting.	Planting in the new location and mechanical support given.
			
			The photograph was taken about 10 weeks after planting
a	**b**	**c**	**d**

Fig. 1. Main steps of the preparation of stumped buddings with 1-2½ years old rubber plant to be transplanted in a different location

Step 1 is to cut the tap root of the tree to be stumped 2’ below the ground (Fig. 1a). In order to do this successfully, taproot should be exposed by digging the soil from one side and a sharp *“alavangoo”* (crowbar) can be used. Even to prepare stumped buddings, the growth stage of the top most leaf whorl should be fully matured. Once the taproot is separated, then the soil is refilled until the plant recovers from the stress. After about 2 weeks the stem of the tree is cut with a sharp knife or a saw, at 8 feet above the ground level and a lime solution is applied on the stem fully (Fig. 1b). The purpose of this is to minimize transpiration through the stem. After about 2-3 weeks of the removal of the top part of the tree, the buds on the stem bursts out (Fig. 1c). One should wait for this stage and the tree should be pulled out and transplanted in the new place. It is a 10 feet tall tree and just two feet long tap root located underground will not be sufficient to keep it without moving around. As long as it is unsteady new root developing at the cut end of the tap root can get damaged. Therefore, with the use of some 2-3 wooden sticks, the stem should be supported to be steady without shaking. If these steps are followed with the correct timing, a plant can be successfully transplanted in a new place.

Replacing retarded plants

The other requirement is the replacement of all weak plants. However, weak plants identified by the poor growth, in girth might be due to the bad soil condition, such as very rocky, water- logged, etc., then the next planting hole should be prepared in a better place. Generally, if the girth of a plant is less than half of the average girth of the plants in the clearing, it is considered a weak plant. Most of the weak plants grow into runts at maturity. Runts are similar to vacancies in a way as they do not contribute to the crop of the field. Normally they give minimum crop for a very short period and then dry out. But they occupy a space, aerial as well as underground. Therefore, if there are any runts after 3 years, they can be removed for the benefit of the four plants surrounding them. However, during the first 2½ years period all runts should also be replaced considering them as unproductive plants with 10% extra plants in the field. The whole stand should be of all healthy and productive trees. This is an important agronomic practice needed to increase productivity.

The quality of the plants and the agro management practices during the immature period contribute to the growth of the trees so that they can give the potential yield when they mature. Poor quality plants, will not perform even under the best agro-management practices. Similarly, the best quality plants will grow in to runts if agro-management during the immature phase is neglected. Therefore, the basic practices must be adopted at planting. Failure to do so leads to long- term negative effects. Required growth rates will have to be maintained during the immature phase of growth as tree girth and the yield has a significant positive correlation (Seneviratne, *et al.,* 2008) and in a rubber clearing plants cannot be introduced after 2-3 years and therefore adoption of this technique is the only method available to maintain the recommended number of good quality trees in a rubber field which has a direct and a positive correlation to the productivity of the field.

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FIELD WISE CROP ESTIMATION ENSURES THE SUSTAINABILITY OF RUBBER PLANTATIONS IN SRI LANKA

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INTRODUCTION

Crop estimation is an important activity on an estate. Based on the expected crop, entire expenditure and activities are planned, and if expected crop is not obtained all estate activities get jeopardized. Estimating the crop without proper knowledge of the condition of the rubber fields or rather the trees has lead to overexploitation in many instances. This situation of overexploitation was witnessed clearly from the period of 2007-2008 onwards and the survey conducted on bark auditing and tapping quality during 2010 and 2011, It was found that the condition of the fields, irrespective of the age or the tapping panel that they were tapped on, is highly deteriorated and the trees could not give the estimated crop. To make the situation worse, the strategy adopted by many estates was to tap more and more to achieve the estimates. Though the condition of the trees and the clearings deteriorated further through this, very attractive rubber prices prevailed during this high price period masked the ill effects temporarily. The high rubber price during 2011 was unrealistically high but soon started to drop drastically (Fig. 1). Rubber price in 2011 seems to be the highest for about 50 years. But those who started to enjoy the expenditure lavishly could not curtail the falling rubber price. Also, the cost of production (COP) is on the increase due to various factors such as the increase of labour wages and other unavoidable factors gradually and at present, the cost of production is above the net sale average in many large plantations and estates. The smallholder sector on the other hand maintains the COP at a reasonably low level as there is hardly any overhead charge in their accounts. The objective of this article is to give correct guidance to estimate the crop methodically for every rubber field so that the income is known in advance and all other expenditures on the estate can be prioritized at a manageable level.

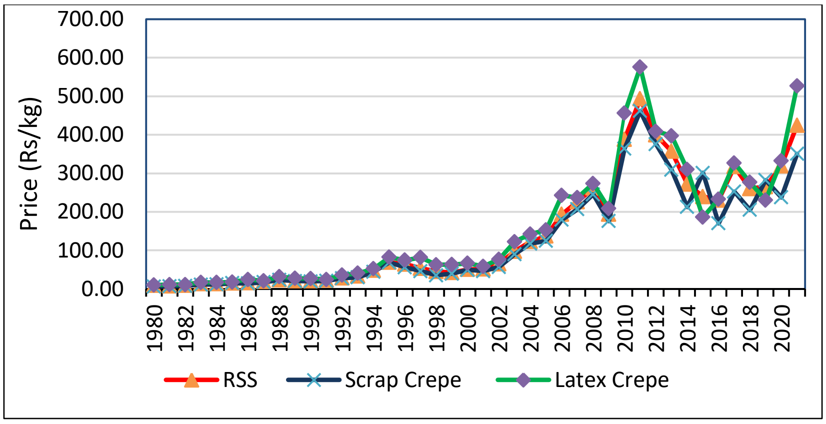

Fig. 1. Rubber price from 1980 to 2020 (Source: Statistics of Rubber Auction, Colombo)

Cropping pattern of rubber fields

The cropping pattern shown in Figure 2 is the basic pattern under normal weather conditions. Yield data of 20 rubber trees of clone RRIC 100 tapped at d2 on virgin panels are used to show the crop pattern. As the wintering in traditional areas is from February to April, the yield declines during that period. This could be due to the tree giving priority to its demands of refoliation and flowering. With the brand new foliage on new twigs, the yield starts to increase gradually till January following year. However, this pattern gets disturbed and deviated often due to many factors such as severe drought conditions, overcast weather with very poor light intensity for long periods, trees getting succumb to diseases such as *Oidium* and *Phytophthora*. Therefore, crop estimation is best to be done during the August and October period. The mean annual crop is very close to what is obtained in August (Wijesuriya, *et al.*, 1997).

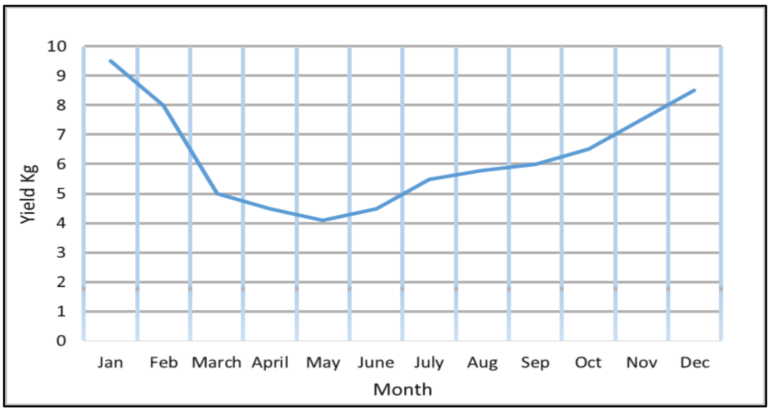

Fig. 2. Annual cropping pattern of a rubber clearing in traditional rubber growing areas (Yield data of 20 rubber trees of clone RRIC 100 tapped at d2 on virgin panel)

Figure 3 shows the cropping pattern of the clone RRIC 100 tapped at S/2 d3 with ethrel for two years at the Kuruwita substation in the Ratnapura district which belongs to WL1 Agroecological Zone. In 2018, the pattern behaves according to the normal pattern but in the year 2019, due to severe drought at the beginning of the year, the leaf fall and re-foliation have completed within two months and heavy rains prevailed throughout August restricting tapping to minimum days. Then North-East monsoon rain started in October affected the crop to a greater extent. Accordingly, the chances remain for the estimates getting affected by natural disastrous conditions.

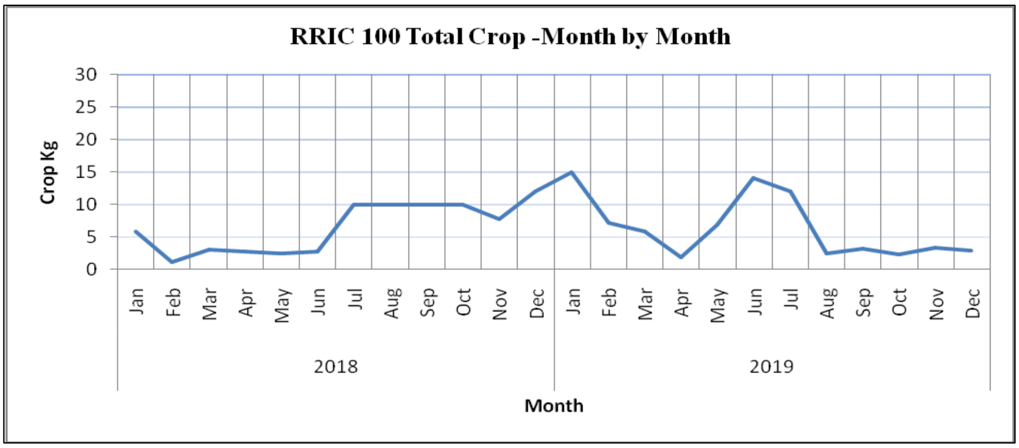

Fig. 3. Annual crop pattern of the clone RRIC 100 tapped at S/2 d3 with ethrel stimulation at Kuruwita Sub Station. Data show the total crop of 30 trees for two years

Calculation of the crop

Actual yields obtained from under the recommended tapping systems, *viz.* d2, d3 or d4, depending on the clone, the condition of the trees and all other factors such as availability of skilled tappers and they should all be considered for the crop estimation. No double tapping or recovery tapping should be practiced during this period as it may affect the correct potential crop from the field.

Yield data collection per block needs to be continued at least for a three months period. As explained above, to get accurate results it is recommended to collect crop data from August to October. Using the data for each day, the average yield per block should be calculated.

The example given below is to help to calculate the estimated crop from each block. In order to do it, g/t/t (the yield in grams per tree per tapping) should be known. g/t/t can be calculated using equation (1). Then the estimated yield per hectare can be calculated using equation (2).

$$gt^{-1}t^{-1} = \frac{(V_B \ X \ DRC_B \ X \ 1000)}{T_B} \quad \text{---------} \quad (1)$$

$$Estimated \ YPH \ = \frac{(gt^{-1}t^{-1} \ X \ TD \ X \ T_H)}{1000} \quad \text{---------} \quad (2)$$

Where,

$gt^{-1}t^{-1}$	- yield in grams per tree per tapping
V_B	- the volume of latex per block in liters
DRC_B	- dry rubber content in grams
T_B	- number of tappable trees in the block
$Estimated \ YPH$	- estimated yield per hectare in kilograms
TD	- number of tapping days per year
T_H	- number of tappable trees per hectare

Eg:

Number of tappable trees in a tapping block	- 260
Total volume of latex /block / day	- 25 liters
Metrolac reading	- 130 (DRC -36%)
Extent	- 3.5 ha.
Total number of harvestable trees in the area	= 1,100
Average no. of trees/ha. (1,100/3.5)	= 314

If the estimated total tapping days/year is 320 and the tapping system is S/2 d2
Total tapping days/tree/year per block is 160

Using equation (1)

$$gt^{-1}t^{-1} \ = \frac{(25 \ X \ .36 \ X \ 1000)}{260} \quad = 34$$

Using equation (2)

$$Estimated \ YPH = \frac{34 \ X \ 160 \ X \ 314}{1000}$$

$Estimated \ YPH = 1708$kg

Crop pattern of a tree

The yield that can be obtained from a field depends on many factors such as the clone, growth condition of the trees, year of tapping, ground condition and nutritional status and quality of tapping, tapping system, *etc*. Prevailing weather, disease incidences *etc*., also equally affect the yield.

Annually 4-5 kg of rubber can be obtained from any tree that belongs to any clone. The general yield pattern of a tree or a clearing during its life cycle is as in

Table 1. But the actual situation can be very different from this pattern due to reasons unique to different fields.

Once the crop of the field is calculated properly, the estimation of the crop of each field should be calculated based on the crop pattern of the life cycle. The panel position based on the harvesting system is the main concern for this. Figure 4 is for a normal field tapped at d2 frequency where each panel is harvested for six years. Many clones are slow starters and the crop increases gradually and on average annually. Table 1 shows the panel tapped and the expected yield increase due to the change of the tapping panel and the position and also the number of tapping cuts.

Table 1. *The general yield pattern of a tree or a clearing during its life cycle*

Year of tapping	**Expected average crop per tree per year (kg)**	**Expected change in panel**
1st year	2-3 for slow starters	The very first virgin panel BOI, A1
2nd year	an increase of about 20% from 1st year	The same virgin panel BOI, A2
3rd - 6th year	an increase of about 10% from the previous year	Panel BOI, A3 ⟶ A6 As the panel moves down, the girth increases and the tree is getting matured but the drainage are decreases.
7th -12th year	Only a slight increase in crop annually	The second virgin panel BO 2. The length of the tapping cut increases as the panel moves down and the bark thickness is higher than BOI.
13th -18th year	Only a slight increase	The first renewed panel of B1 – 1. Generally, a good yield is expected.
19th - 21st year	an increase of 25% on the previous year	The second renewed panel of BI 2 Quarter cut on upper panel, HO2 is commenced with B1 – 2. 1½ years on each quarter cut, for 3 years.
22nd - 23rd year	an increase of 15% from 21st year but no change in 23rd year	2 Half spiral cut on HO 2 and B1 2 due to additional upward ¼ length.
24th year	an increase of 15% from the previous year	Four half spiral cuts on HO - 2 and HO2, B1 – 2 and B2 – I

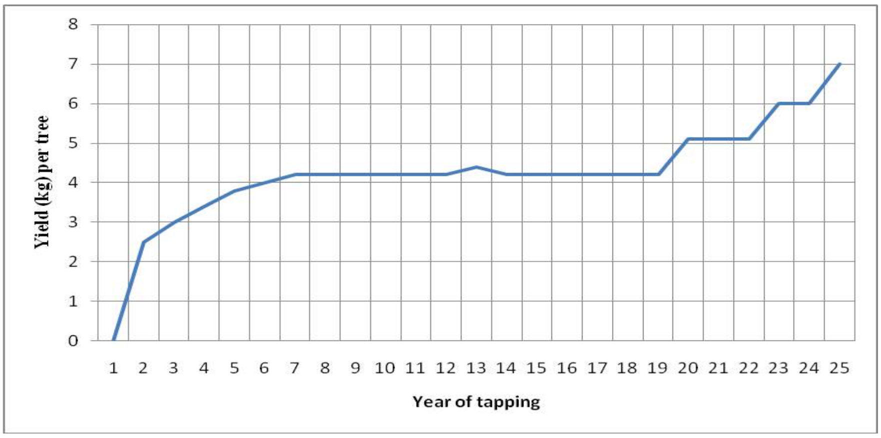

Fig. 4. The general crop pattern during the life cycle of a tree

It should be mentioned that this crop pattern can be varied according to the clone, condition of the trees and the clearing, weather pattern disease incidences, *etc.* to a greater extent. Figure 5 explains the panel position during the 24 years of tapping.

Fig. 5. Schematic diagram showing the year of tapping and expected panel positions under S/2 d2 tapping

Though the tapping year and the expected panel positions should be as in Figure 5, under S/2 d2 tapping, in most cases, overexploitation is experienced when bark auditing is done. The remedy for overexploitation is generally to stop on overexploited base panels and commence a ¼ upward cut until the correct panel position against the year of tapping is experienced. The reason for overexploitation is also to cover the estimates, in order to run estates. This seems a vicious cycle to which many estates have already entered. Therefore, to arrest this situation, a correct field wise crop estimation should be done, and then only by adopting a strategic plan, unique to each estate, sustainable yields and sustainable plantation industry can be expected.

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COCONUT HUSKS TO REDUCE THE TOP SOIL REQUIREMENT IN YOUNG BUDDING RUBBER PLANT PRODUCTION WHILE SOLVING TAP ROOT COILING AT THE BASE

Priyani Seneviratne and G A S Wijesekara

INTRODUCTION

Annual rubber planting material production in Sri Lanka is in the range of 2-3 million to maintain the current extent of 130,000 ha under rubber Anon (2017). In order to fulfill this requirement of plants, the Rubber Development Department maintains eight large scale rubber nurseries and estates under Regional Plantation Companies, has about 100 nurseries at varying capacities to cater to their planting material requirement. Private rubber nurseries are gradually moving away from the business as demand for planting material is decreasing due to decreasing rubber prices. The currently recommended size of the polybag for raising young buddings is 6” x 15” and the volume of soil per bag is 2500 cc. For the production of two million plants the soil requirement is 5000 m^3. Though the recommendation is to use top soil, the availability of top soil is becoming limited. Several attempts were made earlier also to substitute soil with sand, compost, coir pith *etc*., and it was found a mixtures of top soil, sand, compost and coir pith was better than soil alone (Seneviratne, 2009). However, at present compost @ 50g/bag is recommended with top soil to fill bags (Advisory Circular, Fertilizer to rubber). Coir pith was available at a reasonable price but with the emergence of export market it is not economical to use it as a potting mixture for rubber nurseries as the volume required per bag is high. The objective of the present study is to investigate the possibility of reducing the soil requirement by adding coconut husks in to the bags with soil.

Materials and Methods

Seeds collected in the seed fall of 2009 were used for this study. Preparation of the bags and the potting mixture was as in Table 1. Polybags of recommended size were used. A central hole of 1” x 1” at the base of the bag was included as a treatment to exclude the effect of root coiling at the base. There were 25 plants per treatment. Nursery arrangement and after-care of the plants were done as per the Advisory Circular on Production of Budded Plants. Potting media tested, preparation of the bags and % of soil saved by weight are given in Table 1.

Table 1. *Potting media tested and the amount of soil that is saved*

Treatment	% of soil saved (by weight)
T_1 Top soil + two coconut husks cut into pieces (about 2" size)	26
T_2 Top soil + two coconut husks as whole	22
T_3 Top soil + two coconut husks cut into halves vertically	22
T_4 Top soil + hole at the base + perforation	0
T_5 Top soil + hole at the base only (no perforation)	0
T_6 Top soil + perforation (control)	0

Coconut husks were found locally and medium size husks were used. One husk in the treatment mentioned above was equal to one fourth of a husk of one nut. Plants were budgrafted with clone RRISL 210. Growth of the plants measured as diameter and height of the plants SEM.

Results

Mean height and the diameter measured after 10 weeks of planting seedlings in bags are shown in Table 2.

Table 2. *The mean diameter and height of the seedlings after 10 weeks SEM values are given in brackets*

Treatment	Growth of the plants	
	Height (cm)	Diameter (mm)
T_1 Top soil + two coconut husks cut into pieces (about 2" size)	59.3 (±2.04)	7.09 (±0.17)
T_2 Top soil + two coconut husks as whole	56.9 (±1.52)	7.31 (±0.15)
T_3 Top soil + two coconut husks cut into halves vertically	54.2 (±1.26)	6.8 (±0.12)
T_4 Top soil + hole at the base + perforation	56.1 (±1.3)	6.95 (±0.32)
T_5 Top soil + hole at the base only (no perforation)	54.6 (±1.21)	7.0 (±0.1)
T_6 Top soil + perforation (control)	55.5 (±1.38)	6.9 (±0.12)

Height of the seedlings varies from 54.2 cm to 59.3 cm. Diameter values vary from 6.8 mm to 7.3 mm and plants of all treatments have reached buddable size of above 6 mm diameter. The effects of the potting medium, presence of perforation or the presence of central hole at the base of the bag show no significant differences among treatments for the height or the diameter.

The mean diameter (mm) and the mean height (cm) of the scion shoot, five months after bud grafting is given in Table 3.

Table 3. *Mean diameter (mm) and height (cm)of the scion shoot, five months after bud grafting*

Treatment	Growth of the plants	
	Mean height (cm)	**Mean diameter (mm)**
T_1 Top soil + two coconut husks cut into pieces (about 2" size)	46 (±5.54)	8.6 (±0.35)
T_2 Top soil + two coconut husks as whole	33.3 (±5.84)	9.0 (±0.39)
T_3 Top soil + two coconut husks cut into halves vertically	54.1 (±3.65)	9.3 (±0.38)
T_4 Top soil + hole at the base + perforation	44.5 (±3.37)	8.8 (±0.39)
T_5 Top soil + hole at the base only (no perforation)	49.9 (±3.11)	9.1 (±0.31)
T_6 Top soil + perforation (control)	43.3 (±3)	8.7 (±0.341)

As per the data, mean height of the scion shoots which occur in flushes are not significantly different due to very high SEM values. Mean diameter values vary from 8.6 mm to 9.3 mm. T_5 and T_6 compare the presence of central hole at the base and indicate better growth when the bag has central hole without perforation though not significant.

All plants were field planted at the two whorled stage and the mean girth (cm) of the trees after one year in the field are given in Figure 1.

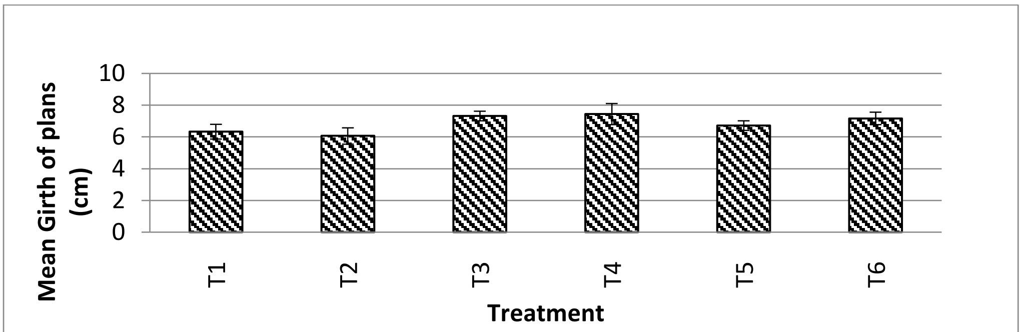

Fig. 1. Mean girth (cm) of the trees after one year of field planting. SEM values are marked on the columns. T_1 Top soil + two coconut husks cut into pieces, T_2 Top soil + two full coconut husks, T_3 Top soil + two coconut husks cut into halves, T_4 Top soil + hole at the base + perforation, T_5 Top soil + hole at the base, T_6 Top soil + perforation (control)

Data shows no significant difference among treatments and the growth is more uniform as indicated by low SEM compared to seedling data where SEM is higher. Growth of all plants in all treatments is satisfactory.

Discussion

Results of the present study indicate that soil can be successfully substituted with coconut husks. Two coconut husks included as a whole, cut into two or cut into pieces have given similar results. As coconut husks are easy to find and easy to inset while filling bags, the top soil requirement can be reduced significantly. Also the physical properties of the medium is expected to be improved with the presence of coconut husks, perhaps due to improved moisture absorbed by them. A similar attempt has been made by Cahyo *et al.*, (2019) but they have used coco peat and recommend soaking coco peat before using it in bags. They have tested cocopeat from 0% to 100% with top soil and the plant height, plant diameter, fresh weight and dry weight have been reported. The diameter values for all treatments are in the range from 0.64 cm to 0.9 cm and most interestingly increase gradually with the increase of % of coco peat in the medium. They conclude cocopeat: soil 80:20 as the best medium and also mention of growth inhibition with 100% cocopeat, which is not seen in the data.

In the present study also, height and diameter values are in par with the values reported by them.

Further, adding two coconut husks has reduced the weight of the soil filled bag by 22-26% in the present study which is very much advantageous ergonomically as carrying bags and plants will be easier with reduced weight.

It should also be emphasized that as mentioned in many studies conducted with potting media, the effect of the medium is minimum as the tap root penetrates bag after 4-5 weeks of planting the seedling in the bag. Therefore, the purpose of the potting medium should be to provide the plant with the temporary support for a period of about 10 months. Plant quality is independent of the potting medium and the performance of the plants will be entitled when they are field planted.

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EFFECT OF TYPE AND LOADING OF BLOWING AGENTS ON CURE CHARACTERISTICS OF NATURAL RUBBER CELLULAR COMPOUNDS

U A Weerasinghe, W P P T Wickramaachchi and W D M Sampath

INTRODUCTION

Polymer materials have been made in different forms such as soft grade, hard grade and medium hard grade. Soft grade polymeric materials have unique features such as low weight, ability to change shape, impact damping and energy absorbing characteristics (Harnnarongchai and Chaochanchaikul, 2015). Therefore, nowadays most of the researchers have reported different applications and advantages in regard to soft grade polymer materials like cellular or sponge materials (Samsudin *et al.*, 2017). These materials have been made by incorporation of low boiling point blowing agents (BAs), foaming agents, plasticizers, *etc.* into synthetic or natural polymers. Natural rubber (NR) which is extracted from latex obtained from "*Hevea brasiliensis"* tree plays a major role when it comes to natural polymer materials which are widely used in foam product manufacturing. The unique features of NR have enabled the industry to generate a wide variety of NR foam products.

Cellular or sponge materials have been manufactured by using dry rubber and latex, when it comes to NR products. Most of cellular materials have been made using latex. Cellular materials formed with latex have low dimensional stability, hardness as well as low strength and requires chemical stabilization, which can be affected by storage time and environmental factors at the initial stage. In contrast, dry rubber based cellular compounds have more rigid physical and structural properties compared to the latex based cellular compounds due to the differences involved in manufacturing process and raw materials (Ariff *et al.*, 2007).

Further, cellular compounds can also be categorized under two main types according to the structural configuration namely; *open cell structures* and *closed cell structures*. Cells in *open cell structures* are interconnected in an opened manner so that liquid and gas molecules can penetrate easily through the structure. The *closed cell structure* as its name implies has mainly closed cells, where gas is trapped in the cells formed and with a minor share of open cell structures. Therefore, the penetration of liquid and gas molecules through the material is hard to achieve in closed cell structures.

The physical and chemical characteristics of the cellular products depend on several factors such as the nature of the polymer selected, blowing temperature, nature and loading of blowing/foaming agent introduced to the system and variation in other materials incorporated into the formulation (Sombatsompop and Lertkamolsin, 2000) (Lee and Choi, 2007). In fact, morphology of cellular materials is significantly responsible for property variation of end products. Several types of blowing agents are used to form cellular compounds in solid, liquid and gas stages depending on the desired morphology to achieve. Inorganic blowing agents such as sodium bicarbonate ($NaHCO_3$) are preferably used to obtain open cellular structures, while organic blowing agents such as azodicarbonamide, dinitrosopentamethylenetetramine (DNPT), isopropanol are used in manufacture of closed cellular structures. The foaming process takes place when the blowing agent generates gases such as nitrogen, carbon dioxide, carbon monoxide, hydrogen at elevated temperatures and these gases produced create the cellular structure.

Samsudin *et al.* (2017) studied the effect of blowing agent concentration and compression strain rate and found out that the compression stress of the foam decreased with increasing blowing agent concentration due to the decrease in relative density. Furthermore, it was found that the effect of the compression strain rate was only detected on foams with low blowing agent concentrations.

Most of the work reported on cellular products have been focused on latex based ones. The properties of dry rubber based cellular materials have not been studied in detail. In this study, cellular compounds were prepared with dry natural rubber and cellular compounds were evaluated by using different blowing agents namely sodium bicarbonate, dinitrosopentamethylenetetramine (DNPT) and isopropanol. In addition, each series of cellular compounds were prepared by varying the blowing agent loading from 2 to 10 phr at 2 phr intervals.

The selection of the three blowing agents (BAs) was mainly based on the structure of the foam produced, *i.e.* whether open/closed cell. Among those DNPT is widely used in commercial applications as a solid BA material, which provides closed cell structures (Tangboriboon *et al.*, 2015). The other two BAs selected; $NaHCO_3$ provides open cell structure and isopropanol provides closed cell structure. Isopropanol is a liquid BA and has not been vastly studied in the area of cellular materials.

Methodology

Materials

The crepe rubber used for this study was supplied by the Rubber Research Institute of Sri Lanka, Dartonfield and the other ingredients were sourced by local market.

Three types of cellular compounds were prepared, one with open cell structure and two with closed cell structures. Different loadings of $NaHCO_3$, DNPT and isopropanol blowing agents were introduced to the system as given in Table 1. Compounding was done using a two roll mill and the compound moulding was carried out in a hydraulic press machine at a temperature of 150℃ and pressure of zero bar for twenty minutes.

Table 1. *Formulation of the samples*

Material	Quantity (phr)
Crepe rubber (1X)	100
ZnO	5
Stearic acid	2
TMTD	1
DPG	0.5
White oil	15
WSP	1
Sulphur	1.5
Blowing agent	2/4/6/8/10

Cure characteristics

The cure characteristics of the compounds were evaluated using a Dynamic-Rubber Process Analyzer (D-RPA 3000) according to ASTM D6601 at 150℃ for twenty minutes**.**

The cure rate index (CRI) was calculated according to the following formula,

$$CRI = \frac{100}{Cure\ time\ - \ Scorch\ time}$$

RESULTS AND DISCUSSION

Minimum Torque (M_L)

As the compound is heated under pressure the viscosity of the compound decreases and reaches a minimum torque value. The minimum torque value represents the viscosity and processability of a rubber compound and provides information regarding the stiffness of uncured rubber compound at a given temperature (Najib *et al.*, 2009).

Table 2. *Minimum torque of cellular rubber composites*

Blowing agent loading (phr)	$NaHCO_3$ (dN.m)	DNPT (dN.m)	Isopropanol (dN.m)
2	0.79	0.19	0.46
4	0.37	0.51	0.23
6	0.55	0.49	0.25
8	0.56	0.23	0.24
10	0.41	0.22	0.44

The results indicate that the BA type or loading does not have a significant effect on the compound viscosity prior to crosslinking. However, a general reduction in the trend with the increase in blowing agent can be seen. This can be due to the high viscosity generated for the compounds prepared with low loading of BAs and the decrease in the viscosity of compounds with high loading of BAs as the free volume increases.

Maximum torque (M_H)

With the initiation of the curing process, the torque tends to increase at different rates depending on the type of BA and loading. This will reach to a maximum torque with the completion of the formation of crosslinks. The value given by M_H correlates to the static/storage modulus (shear modulus) or the stiffness of the fully vulcanized compound (Charoeythornkhajhornchai *et al.*, 2017)and state of crosslinking of the vulcanizate.

Table 3. *Maximum torque of cellular rubber composites*

Blowing agent loading (phr)	$NaHCO_3$ (dN.m)	DNPT (dN.m)	Isopropanol (dN.m)
2	6.30	11.11	6.42
4	6.26	10.30	6.22
6	6.21	10.19	6.14
8	5.75	9.12	6.13
10	5.26	8.60	6.14

The trend of the results presented in the above table indicates two main observations. As the BA loading increases the M_H values tend to decrease. Secondly, when comparing the three types of BAs it is clear that DNPT based foam rubber has the highest M_H values, while $NaHCO_3$ and isopropanol BAs incorporated foam vulcanizates indicate relatively low, but almost similar values.

The reason for the decreasing trend could be explained by the increase in gas generation during the decomposition process of BAs as the loading is increased. This generates more microvoids in the gas or rubber phase, which leads to lower the storage modulus and stiffness of the vulcanized compound. This observation is further evident by the studies on the effect of BA on cell morphology, impact properties of NR foam and structure optimization of polycaprolactone foams carried out by Najib *et al.* (2009) and Di Maio *et al.* (2005), respectively.

The reason for the second observation where the compound prepared with DNPT has obtained a higher M_H value could be explained with the types of gases generated throughout the process. The study carried out by Di Maio *et al.*, (2005) revealed that compared to N_2, CO_2 is more soluble in the polymer material and tends to generate cellular structures with lower densities. During the decomposition process $NaHCO_3$ and Isopropanol emit CO_2 and CO gases, while DNPT emits N_2 gas. As a result, the stiffness of the material generated using DNPT as the BA has a higher M_H value compared to foam rubber produced using $NaHCO_3$ and Isopropanol as BAs.

Scorch time (TS_2)

TS_2 is the time taken to onset of crosslink formation, which is generally measured as the time taken to increase the rheometer torque value by two units above the minimum. It is measured in time units and provides an information regarding premature cure or processing safety.

Table 4. *Scorch time (TS_2) of cellular rubber composites*

Blowing agent loading (phr)	$NaHCO_3$ (min)	DNPT (min)	Isopropanol (min)
2	0.79	3.18	2.77
4	0.76	2.90	2.56
6	0.62	2.85	2.54
8	0.58	4.75	2.32
10	0.60	3.04	2.31

Results presented in Table 4 show a decreasing trend in scorch time as the BA loading increases indicating a lower processing safety. The higher BA loading leads to lower the relative density (Najib *et al*., 2009) of the cellular compound due to the emergence of gas phase. This enables the compound to generate cellular structures enabling easy deformation to take place. The viscosity of the compound decreases with the increasing BA loading since the resistance to change in shape can be achieved by a low energy. This facilitates the onset of crosslink formation providing a decreasing trend, when the BA loading is increased.

When considering the decomposition temperatures of the three BAs, which are 50℃, 190℃ and 82℃ for $NaHCO_3$, DNPT and Isopropanol, respectively, it indicates that DNPT has the highest decomposition temperature and $NaHCO_3$ has the lowest. The compounds prepared with DNPT indicate higher scorch time due to the greater melting point of DNPT compared to $NaHCO_3$. The lower decomposition temperature of $NaHCO_3$ would enhance the rate of evolution of gas and hence onset of curing would be easier as curing ingredients could react with rubber molecules easily as all these will be more closely situated to each other. This results in a lower scorch time or processing safety for compound prepared with $NaHCO_3$, when compared to that prepared with the other two BAs.

Cure time (T_{90})

This represents the time at which 90% curing has taken place and it is generally referred to as the optimum cure time. As expected, the trend in the variation of cure time is similar to that of the scorch time.

The decomposition temperature is represented from the trend of cure time, where the highest cure time is obtained by DNPT based compound followed by Isopropanol and $NaHCO_3$ based compounds. The gas molecules present in the cellular compound help to generate thin cell walls within the compound, which increases the potential of the activators and accelerators to react more easily with the vulcanizing agent to form the active sulphurating agent and thereafter crosslinks with rubber molecules as explained earlier. Hence, the increase in gas phase and cells within the compound facilitate the vulcanization process resulting in lowering of cure time as the loading of BA increases.

According to the results tabulated in Table 5, it can be seen that the generation of open cells happens at high efficiency with the use of $NaHCO_3$.This observation is evident from the study carried out by Di Maio *et al.* (2005) for polycaprolactone foams, where it was found that compared to N_2 gas CO_2 gas was much more soluble inthe polymer more efficiently. This can be a possible reason for compounds prepared with $NaHCO_3$ and isopropanol to have lower cure times than those prepared with DNPT.

Table 5. *Cure time of cellular rubber composites*

Blowing agent loading (phr)	**$NaHCO_3$ (min)**	**DNPT (min)**	**Isopropanol (min)**
2	1.24	10.53	4.62
4	1.11	10.23	4.23
6	1.07	10.15	4.20
8	0.95	14.68	3.79
10	0.95	7.85	3.74

Cure Rate Index (CRI)

The CRI represents an indication of rate of vulcanization and the results are in agreement with those of cure time. According to the data available in Table 6 it can be seen that cure rate increases with the increase in BA loading, and the highest rate is obtained by the compounds with $NaHCO_3$. This indicates that the structural transition of the compound affects directly the rate of vulcanization and is increased when the gas phase present in the compound is increased. Additionally the structure having open cells prefers to have a higher rate than closed cell structures. This can happen due to the easy access of the compounding ingredients through the cell walls and efficient reaction of the same.

Table 6. *Cure Rate Index (CRI)of cellular rubber composites*

Blowing agent loading (phr)	**$NaHCO_3$ (min^{-1})**	**DNPT (min^{-1})**	**Isopropanol (min^{-1})**
2	222.22	13.61	54.05
4	285.71	13.64	59.88
6	222.22	13.69	60.24
8	270.27	10.07	68.03
10	285.71	20.79	69.93

CONCLUSIONS

This study revealed that the maximum torque, cure time and cure rate index results indicated remarkable cure property transition with the addition of BAs. The decreasing trend of maximum torque indicates the increase in gas generation as well as the distinct properties of the final product according to the type of decomposition gas as the BA loading increases. The decrease in cure time and the increase in cure rate index exhibit the increase in the efficiency of the vulcanization reaction as the BA loading is increased.

This implies that the effect of BA not only generates a structural transition within the compound but also helps to accelerate the vulcanizing process. Therefore in a way the blowing agents can be categorized as agents, which facilitate the vulcanization reaction by acting as a co-activator within the system. Additionally, the significant differences in results among each BA indicate the changes in cure characteristics according to the type of cells generated throughout the decomposition process as well as the type of gas generated. Therefore when it comes to applications, considering the results of maximum torque, selection of the suitable BA according to the requirements can be a critical point. However, DNPT BA with a moderate loading of 6 phr can be used for the production of floatable swimming articles, shock absorbers, personal protective equipment such as safety jackets and $NaHCO_{3,}$ isopropanol BAs can be used for makeup sponges, cleaning sponges, shoe soles, *etc*. Furthermore, a blend of these BAs could be used innovatively in the future to construct cellular materials as a carrier medium for slow release fertilizers, which provide essential nutrients to plants.

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RAINFALL VARIABILITY AT DARTONFIELD, AGALAWATTA IN LOW COUNTRY WET ZONE (WL_{1a}): ANALYSIS OF PAST 57 YEARS DATA

Wasana Wijesuriya, Dilhan Rathnayaka and Vidura Abeywardena

INTRODUCTION

Climate change and its variability are considered a popular topic in media, popular science articles and many other sources of information. These changes interfere with the biological phenomena causing different impacts on plant growth and hence productivity; and the rubber tree is not an exception. Rubber production depends on good management practices and factors mostly related to the weather obviously, and the growers have no control. Rainfall affects rubber plantations in two ways. During its immature period, moisture is essential for optimum growth. Whilst when matured, the number of rainy days determines the number of tapping days and ultimately the economic yield of rubber.

Rainfall affects the rubber tree at all stages of growth from planting until felling and therefore it is of great concern to the rubber grower. Thus, it is essential to have a total of 500 mm in any consecutive six months and also a total annual rainfall not less than 1650 mm. It is emphasized that uniformly distributed rainfall is required for the maintenance of growth and latex production of rubber trees. Hence, any changes in the seasonal pattern may obstruct the application of recommended agronomic practices in rubber plantations. Apart from the management practices, disease incidence, flowering, pod set and pod ripening are closely linked with the seasonal pattern of weather factors. Some studies revealed low seed production in most of the rubber growing areas in the Wet Zone and have become a major threat in the production of quality planting materials. During recent years, several leaf diseases also appeared as epidemics due to the conducive weather pattern for the initiation and spreading of leaf diseases (Anon., 2019).

As a consequence, having an idea about any changes in rainfall is of paramount importance for the management of rubber plantations. This article is based on the meteorological data collected at the AGROMET[1] station at Dartonfield, Agalawatta located in the Agro-Ecological Region (AER), WL_{1a}. This article revisits the former that appeared in the RRISL Bulletin on a similar topic by Wijesuriya *et al.* (2001) covering the data from 1964 to 2000 and 1971 to 2000, for yearly and monthly bases. Long-term variations in annual, seasonal and monthly rainfall are discussed in this article covering the above periods and extends to December 2020

[1] Agro-meteorological network was commenced in 1973 with the guidance and donations given by United Nations Development Programme (UNDP). With this, the AGROMET stations were established island wide under certain institutions such as coconut research, rubber research, tea research and in agriculture research stations at the beginning. Now, there are 41 such stations island wide.

METHODOLOGY

Data

Data on rainfall availability at the meteorological station at Dartonfield cover the period from 1964 to 2020 and 1981 to 2020, on yearly and monthly bases. The base periods suggested by World Meteorological Organization [WMO] (Anon., 2017), *viz.* 1961 to 1991, 1981 to 2010 and 1991 to 2020 were used in the analysis. Further, the standard statistical methods described in the WMO Guidelines on the calculation of Climate Normals were employed in data analysis.

RESULTS AND DISCUSSION

Annual rainfall

The annual rainfall observed since 1964 is presented in Fig. 1, which indicates a random event with frequent rises and falls in the series. The lowest annual rainfall total (2966 mm) was observed in 2016 whilst the highest was 5660 mm in 2008. The average annual rainfall for the period from 1964 to 2020 is 4189 mm with a standard deviation of 554 mm. The statistics for annual rainfall for different base periods adopted by WMO are listed in Table 1 with more or less similar statistics.

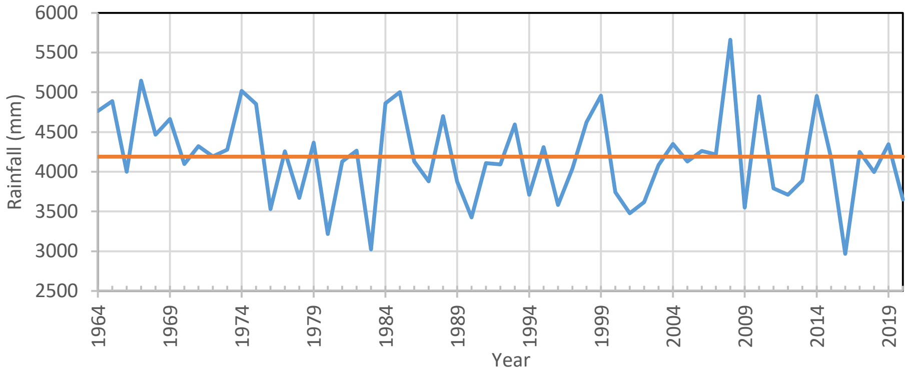

Fig. 1. Total annual rainfall experienced at Dartonfield since 1964

Table 1. *Descriptive statistics of annual rainfall for different base periods according to WMO*

Period	Average annual rainfall (mm)	Standard deviation (SD) (mm)	Coefficient of variation (CV %)
1964-2020[1]	4189	554	13.2
1964-1990[2]	4259	563	13.2
1981-2010[2]	4178	567	13.6
1991-2020[2]	4125	545	13.2

[1] Overall mean

[2] Base periods suggested by WMO

Total number of wet days per year

As evident in Table 2, the total number of wet days under different categories of periods did not show any marked differences. A wet day is defined as a day with rainfall >= 1.0 mm (WMO, 2017). During the recent past 30 years from1991 to 2020, an average of 205 wet days was observed with a range of 186 to 228. The number of wet days in other categories was in the range of 20 and 39, 135 and 181 and 8 to 34, respectively, in <=2.5 mm, 2.5-50 mm and >50 mm categories.

Table 2. *Descriptive statistics of the number of rainy days per year for different periods*

Period	Number of rainy days			
	>=1 mm	**<=2.5 mm**	**2.5-50 mm**	**>50 mm**
1964-2020	207 (13.90)	30 (5.95)	157 (12.22)	20 (4.62)
1964-1990	209 (16.36)	31 (6.45)	159 (13.26)	20 (3.81)
1981-2010	204 (14.28)	29 (5.70)	154 (12.14)	21 (5.00)
1991-2020	205 (11.18)	30 (5.52)	156 (11.25)	20 (5.31)

* Standard deviations are given in parentheses

The number of rainy days in the four rainy seasons according to rainfall categories is given in Table 3. It seems that the number of rainy days has not changed much in different base periods and also showed more or less similar variability in different rainy seasons under the rainfall categories considered.

Table 3. *Descriptive statistics for the number of rainy days in different rainy seasons for different base periods*

	Number of rainy days			
Rainy season	**>=1 mm**	**<=2.5 mm**	**2.5-50 mm**	**>50 mm**
Base period 1964 - 2020				
North East	32 (7.88)	5 (2.57)	24 (6.65)	2 (1.83)
Inter-monsoon 1	32 (7.13)	4 (2.13)	24 (5.63)	3 (1.90)
South West	103 (8.86)	16 (3.96)	78 (9.00)	9 (3.35)
Inter-monsoon 2	40 (5.80)	5 (2.44)	31 (5.25)	5 (2.28)
Base period 1964-1990				
North East	31 (8.25)	5 (2.43)	24 (6.92)	2 (1.81)
Inter-monsoon 1	33 (7.99)	5 (1.97)	25 (5.98)	4 (2.15)
South West	103 (8.92)	16 (3.66)	78 (9.00)	9 (2.95)
Inter-monsoon 2	41 (6.82)	5 (2.76)	31 (5.80)	5 (2.00)
Base period 1981-2010				
North East	31 (9.51)	5 (2.57)	23 (7.53)	3 (1.90)
Inter-monsoon 1	30 (7.25)	4 (2.14)	23 (5.75)	4 (1.94)
South West	102 (9.02)	15 (3.90)	77 (9.01)	10 (3.72)
Inter-monsoon 2	40 (5.63)	4 (2.75)	31 (5.54)	5 (2.47)
Base period 1991-2020				
North East	32 (7.68)	5 (2.73)	24 (6.53)	3 (1.81)
Inter-monsoon 1	30 (6.11)	4 (2.19)	24 (5.36)	3 (1.57)
South West	103 (8.95)	16 (4.26)	78 (9.15)	9 (3.72)
Inter-monsoon 2	40 (4.81)	5 (2.16)	30 (4.18)	5 (2.53)

*Standard deviations are given in parentheses

Monthly rainfall

The Dartonfield meteorological station is located in the Agro-ecological Zone WL_{1a}, where the rainfall pattern is bimodal with peaks coinciding May/June and October/November periods. The 75% expected rainfall in each month (lower quartile) concerning the period 1991 to 2020 is depicted in Fig. 2. The peak in May (385 mm) is generally higher when compared to the peak (370 mm) in October. February experiences the lowest (58 mm) followed by 102 mm in January. March, July, August and December have monthly 75% expected value falling in the range of 127-194 mm. The wet months; April, May, June and September, October, November have rainfall totals exceeding 250 mm.

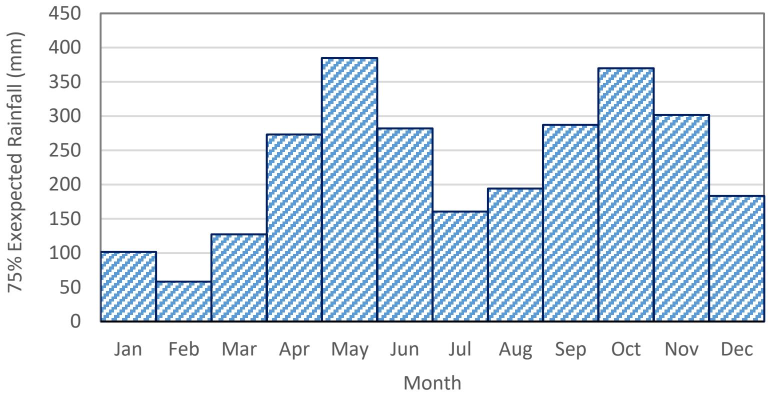

Fig. 2. The 75% expected rainfall in each month (period 1991 to 2020)

Monthly totals of rainfall experienced in the period, 2001-2020 are presented in Fig. 3, together with the average monthly distribution in the shaded area. The stepped lines over the thick straight line indicate the years with total annual rainfall exceeding the long-term average and stepped lines below the straight line indicate years with rainfall less than the long-term average. The expected bimodal pattern is observed in most of the years except for some deviations in several years. However, in some years, there observed peaks exceeding the normal condition (Fig. 3).

Seasonal rainfall

In general, the rainfall seasons can be broadly classified into four main seasons as listed below.

(a)	North-East rainy season (NE)	- December to February
(b)	First inter-monsoon (IM-1)	- March to April
(c)	South-West rainy season (SW)	- May to September
(d)	Second inter-monsoon (IM-2)	- October to November

During the 1968-2000 period, the South-West (SW) rains brought nearly 47% of the total rainfall while North-East (NE) rains contributed about 13%. The rest of the contribution (38%) came from the inter-monsoons with contributions of 16% and 22%, respectively from IM-1 and IM-2 (Wijesuriya *et al.*, 2001). From 2001 to 2020, the contribution from SW was more or less the same (46%) whilst NE increased to 15%. The contribution from inter-monsoons was also very much similar to the 1968-2000 period.

Occurrence of extreme rainfall events

Rainfall events above 100 mm are considered a potential threat for landslides, especially in the Wet Zone areas. During 1964-2020, out of total events in the period, nearly 30% of them happened during the month of May under the South-West influence. There is a chance of 15% in receiving a rainfall greater than 100 mm in October. The months, April, September and November have nearly a 10% chance to have such events. During the recent base period, 1991-2020, the chance of having rainfall events above 100 mm in the South-West rainy season is about 62%, followed by the second inter-monsoon season (IM2) with a chance of 22% and both first inter-monsoon (IM1) and North East (NE) season have equal chances of 8%.

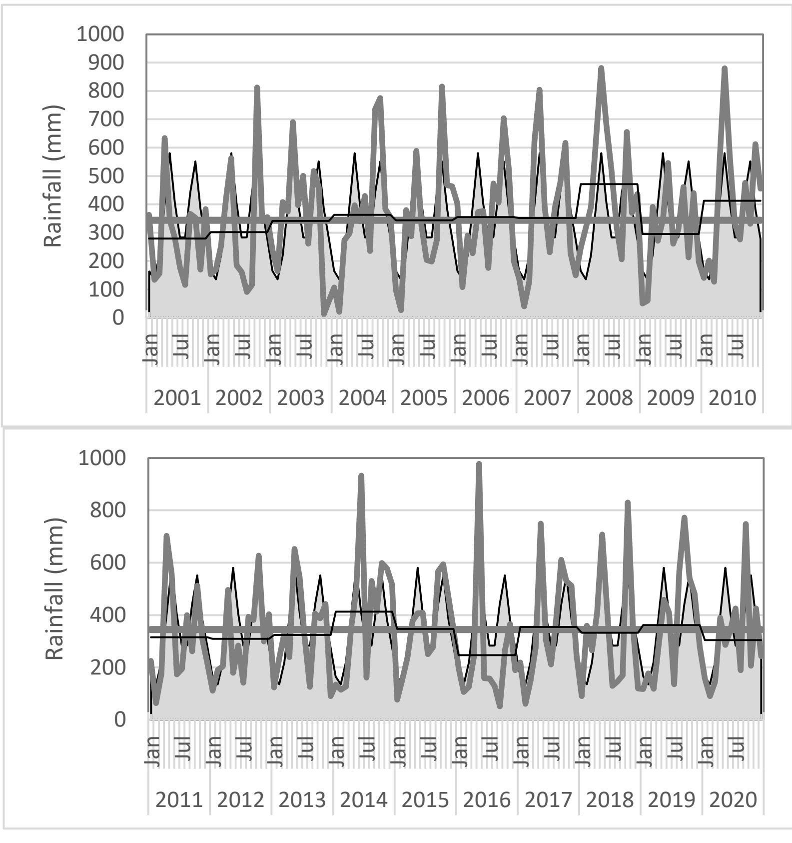

Fig. 3. Deviations from monthly totals from the long-term averages for the period 2001-2020

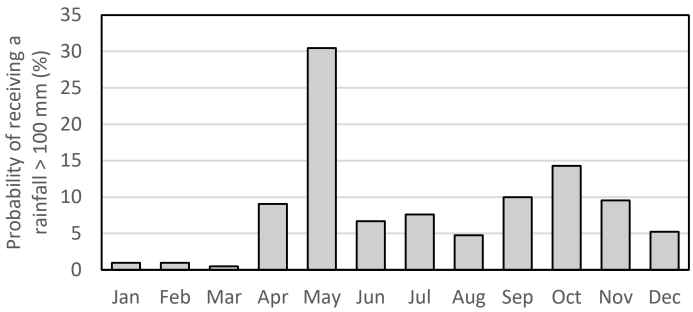

Fig. 4. Probability of receiving rainfall greater than 100 mm at Dartonfield in different months for the period 1964-2020

Occurrence of dry spells

During the first 7 weeks of the year, there appears a fairly long dry spell which can adversely affect the growth of immature rubber plants, especially when planted with North-East Monsoon rains. This observation is supported by the analysis of dry spells at Dartonfield, which is representative of the Wet Zone area, over the period 1964 to 2020 (Table 4). This dry spell during the early part of the year is common to the low country rubber growing areas covering the Agro-Ecological Zones WL_1, WL_2, WL_4, and IL_1.

Prolonged dry spells also affect adversely on the establishment of cover crops, which is an important activity during the initial stages. These cover crops may compete for moisture with rubber plants resulting in a possible growth retardation during dry periods. In this respect, dead and live mulch materials recommended by the Rubber Research Institute would be beneficial to crop growth as it effectively reduces the evapotranspiration demand while not competing with rubber plants for moisture.

Table 4. *The frequency of dry spells during the period 1964 to 2020 - Dartonfield station (WL_{1a})*

Month	**Dry period (days)**				
	6-10	**11-15**	**16-20**	**21-25**	**26-30**
January	35	17	4	3	1
February	32	9	8	3	1
March	26	10	1	1	1
April	8	6	-	-	-
May	9	1	-	-	-
June	4	-	-	-	-
July	16	-	1	-	-
August	14	5	-	-	-
September	17	1	-	-	-
October	13	2	-	-	-
November	15	3	-	-	-
December	33	2	-	-	-

CONCLUSION

The annual rainfall showed a random fluctuation around the mean. Moreover, prominent deviations were not observed in different months and rainfall seasons. These findings can be subsequently used in defining crop calendars, which suit the existing rainfall pattern. Moreover, the information arrived through descriptive analysis reported in this article can be used by the stakeholders for crop management in the Agro-ecological region of WL1a.

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FOUNDRY DUST – A COST EFFECTIVE FILLER IN NATURAL RUBBER PRODUCTS

Nadun Thilakarathne

Sri Lanka generates 7000 MT of solid waste per day. This includes the generation of a large proportion of industrial waste. Incineration is the most popular way of industrial waste management. It could be a great achievement, if Sri Lanka could use the majority of this waste as a reusable material in another industry or convert the same to a value-added product. Also, it will be a milestone in sustainable development and environmental conservation. This article is focused on utilization of foundry industrial waste as filler in natural rubber compounds.

The foundry industry is an important feeder industry for the engineering product sector. It supplies parts and spares for machinery, equipment and tools and specializes in tea, rubber, oil and fiber industries (Sri Lanka Export Development Board). Also, it supplies a wide range of directly exportable metal products. Foundries in operation in Sri Lanka have the production capabilities of grey iron casting, ductile iron casting, aluminum, brass and steel casting after the melting process (Fig. 1). Most of the foundries are scattered in the districts of Kandy, Colombo, Gampaha, Kurunegala, Matara and Hambantota. Nearly 50% of the foundries are located around the Colombo district (Munasinghe and De Silva, 2005). In the Colombo district, foundries can be found in Malabe, Kaduwela, Athurugiriya and Ranala areas and in the Gampaha district these can be found in Kadawatha, Kelaniya and Kiribathgoda areas (Silva, 2020). A large number of medium and large-scale rubber product manufacturing industries are located in the above two districts of the western province. A large proportion of castings are made using granite powder, silica sand and bentonite, naturally bonded sand, or a mixture of sand. An informal foundry industry is spread throughout the country and over 2000 small units are in operation. Waste management in foundry industry is gaining a higher ecological and economic importance. Waste is becoming an increasingly trade product, where excellent profits can be made due to the cost reduction and successful business operation.

Fig. 1. Melting of metal in the foundry industry

This article is based on a research, which was done by Xie *et al.* (2019). It was published by the Multidisciplinary Digital Publishing Institute (MDPI) in the Journal of 'Material' in 2019. The main aim of their study was to evaluate the possibility of applying foundry dust (Fig. 2) derived filler in natural rubber-based industries. Basically, a polymer composite is a mixture of two or more materials, which results in synergistic properties of the components. In a composite, there are two main phases namely, continuous phase and a discontinuous phase. In this research they have used foundry dust as a filler material. Foundry dust is produced in almost every step of the foundry process. A huge amount of dust is generated by mold sand and core sand preparation. The composition of the dust depends on the binder used. Dust is created by casting and felting. The major compound in the dust is SiO_2 and when an organic binder is used it has carbon as well. Depending on the type of furnace, the composition of the dust can vary. However, SiO_2 and Fe are the main constituents. According to studies, foundry waste has some application areas such as fine or coarse fillers in concrete manufacturing, cement production, road bases and embankments (Siddique and Singh, 2011; Iqbal *et al*., 2019). The common method for disposing of foundry waste is to pile it up in landfills, which creates a significant waste of resources and potential environmental pollution (Xie *et al.*, 2019). Incineration is another popular waste management process. However, there are limitations in these methods due to the high transportation cost, scarcity of land and strict environmental laws and regulations.

Fig. 2. Dust generated from the foundry industry

In the paper referred (Xie *et al.*, 2019), a low-cost procedure using sieving, de-ironing and milling was reported. Two kinds of foundry dust were used as filler materials. One was modified foundry dust filler and the other was unmodified foundry dust filler. Compounding ingredients mainly consisted of rubber matrix, reinforcing fillers and other additives. Carbon black and silica are the most widely used reinforcing fillers in rubber composites and the total content can vary depending on the application and its properties. However, carbon black is a non-renewable material and the preparation of silica involves harsh chemicals. The utilization of renewable materials or waste derived materials possessing good reinforcing and processing properties as well as being of low-cost are highly desired in the rubber industry.

Xie *et al.* (2019) selected foundry dust as filler material among the various foundry waste such as sand and slag as the dust particle size of the former is significantly lower than that of other foundry waste materials. Particle size distribution and chemical components were investigated. According to the results of laser particle size analysis and x-ray fluorescence analysis, particles were distributed between 0.4 µm and 50 µm. Irregular shaped particles and particles with different sizes were uniformly distributed. The main elements in foundry dust was detected as O (49.00 wt %), Si (33.74 wt %), Al (6.59 wt %), Ca (2.64 wt %) and Fe (2.40 wt %).

In the preparation process, coarse dust particles were separated using an industrial vibrating screen and magnetic substances such as Fe_2O_3 was separated using a magnetic roller. Subsequently, the ultra-fine powder mill was used to grind the foundry dust in order to obtain fine particles. Thereafter, the qualified powder was sent into the secondary removal of iron. Researchers prepared modified foundry dust powder by reacting it with a silane coupling agent. They prepared three series of natural rubber (NR) composites; without foundry dust, with foundry dust and with modified foundry dust. NR with different contents of filler was compounded on two-roll open mill around ambient temperature. The foundry dust content was varied from 10 to 50 phr at 10 phr intervals. However, the composites contained a constant amount of stearic acid, ZnO, accelerator, antioxidant and sulphur. The homogeneously blended mixtures were stored at ambient environment for 48 hours. Then the mixtures were hot molded at 160 °C for optimal cure time and characterization was conducted. The researchers tested tensile properties, tear strength, hardness, storage modulus and damping factor. These are the main critical parameters, which indicate the compatibility of fillers and the polymer. Also determination of these parameters would imply the application criteria of the material.

The strength of interaction forces between the filler and polymer matrix is the main phenomenon governing filler dispersion in the polymer. Natural rubber is a non-polar polymer. Foundry dust contains elemental oxides such as SiO_2 (72.17%), Al_2O_3 (12.51%), CaO (3.66%) and Fe_2O_3 (3.43%). These oxides are polar and hydrophilic compounds. Therefore, they are not compatible with natural rubber. This affects uniform filler dispersion and mechanical properties of the composite. However, use of a silane coupling agent exhibits the hydrophobicity or non-polar behavior in the foundry dust particle surface. According to researchers, unmodified foundry dust particles tend to form agglomerates in the natural rubber matrix, whereas foundry dust particles uniformly distributed in the natural rubber matrix.

The highest torque value (M_H) of the modified foundry dust/NR composite at 50 phr filler loading was much smaller than the reference carbon black/NR composite at the same filler loading indicating lower reinforcement by the modified foundry dust filler compared to carbon black. Cure time difference between the two composite materials was not significant, which indicated that the two fillers do not have harmful effect on vulcanization of rubber when used together. However, when considering delta cure (M_H–M_L) values between carbon black/NR composite and modified foundry dust/NR composite at 50 phr filler loading, modified foundry dust/NR composite exhibited lower values.

According to the results of mechanical tests, tensile strength of the 50 phr modified foundry dust loaded composite was 15.36 MPa, which is 21% reduction in comparison to that of the pure NR composite. However, it still meets the requirements for many rubber products. Also, tensile strength of unmodified foundry dust composite was lower than that of the modified foundry dust composite. This is because modified foundry dust has better dispersion and interaction forces in NR. In addition, tear strength and hardness improved with incorporation of modified foundry dust. Elongation at break of composites varied in the range of 800 to 1000%, which indicated that the addition of foundry dust has no negative impact on composites. The 50 phr modified foundry dust/NR composite exhibited a large increase in wet grip property and slight increase in rolling resistance (Xie *et al.*, 2019).

Further, Xie *et al.* (2019) have stated that the tested foundry dust sample contained 12.51% of Al_2O_3. Several studies have shown the effect of Al_2O_3 on properties of rubber compounds. Wang *et al.* (2014) have shown that nano scale Al_2O_3 enhances dynamic and static properties of natural rubber composites after treatment with 6 phr of Si 69 coupling agent and heat treatment for 5 min at 150 ºC. Nano Al_2O_3 increase the thermal conductivity of natural rubber matrix under dynamic condition and it extends the service life of composite, significantly. Al_2O_3 incorporated natural rubber compounds have increased electrical conductivity with DCP curing systems (Tangboriboon *et al.*, 2012). Incorporation of surface modified ceramic waste containing SiO_2, Al_2O_3, Na_2O, K_2O, Fe_2O_3 and TiO_2 into NR compounds showed an improvement in mechanical properties such as compression resistance, modulus, hardness and tensile strength (Kondarage *et al.*, 2018). This research conducted in collaboration with the Rubber Research Institute of Sri Lanka (RRISL) suggested that ceramic waste based natural rubber composites could be used as a flooring material. This study has shown compatibility improvement of the inorganic ceramic waste material in the organic natural rubber matrix and mechanical property improvements of their composites.

Recommendations

By investigating the results of the above research, it is possible to recommend foundry dust as a filler in NR composites with acceptable mechanical properties. In particular, the problem of foundry waste can also be solved to a certain extent. According to a small-scale foundry manufacturer, the waste sand quantity generated per month is nearly 400-500 kg. They are not selling or adding any value to it. Allowing to accumulate in a land is the common waste management step of the foundry industry in Sri Lanka. By incorporating foundry dust with carbon black or silica in rubber composites, a synergistic effect on mechanical properties could be achieved. Surface modifications such as using coupling agents, increase the dispersibility of foundry dust in the rubber matrix, while improving the interaction forces between two phases. The use of elemental oxides may improve thermal and electrical conductivities of rubber compounds. Foundry dust will be a better alternative for silica and carbon black up to a certain filler loading. However, trials will have to be conducted with different rubber grades and filler loadings. Rubber product manufacturers should take initiative actions to use these wastes in their productions to reduce the production cost, while maintaining properties of rubber composites. RRISL always welcome rubber product manufacturers to carryout product developments and trials to scale up their productions.

Nowadays, waste management and manufacture of value-added products are hot topics in Sri Lanka as well as in the world. Foundry industries are closely situated to rubber industries and hence transportation cost of material will not affect the budget. Presently, almost all industries are not in operation and facing a huge financial crisis due to the Covid-19 pandemic. Therefore the use of low-cost, high performance waste materials as fillers will help in the sustainability of the rubber industry. Further, it will help to clean the environment of our motherland and pay back us more softly.

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MANUFACTURE OF CREAMED LATEX AS A COTTAGE INDUSTRY FOR PRODUCTION OF NATURAL RUBBER LATEX FOAM

K I D P Perera and D G Edirisinghe

Background

The rubber smallholders contribute immensely to the rubber sector by cultivation of this valuable plantation crop. As the income they earn from the cultivation by selling the raw rubber is not sufficient for their living, it is time for most of them to engage in converting their field latex to one or more finished products. Marketing the products manufactured by them to other countries would increase the foreign exchange earning to Sri Lanka. Fresh natural rubber latex or commonly known field latex obtained from rubber trees is not suitable for manufacture of finished products as it contains a high percentage of water and hence concentrated latex is used for this purpose. Centrifuging is the most widely used concentration process for field latex. Centrifuging is carried out using centrifuging machines and purchase of these machines cannot be afforded by smallholders because of the high cost. Therefore, creaming technique would be the most suitable technique of concentration for smallholders to convert their field latex into concentrated latex with minimum capital investment. Some of the natural rubber (NR) latex based products that can be produced at cottage level using creamed latex include rubber bands, toy balloons, latex coated cotton gloves carpet/rug backings, sponge and foam rubber for fabrication of household furnishings, automotive upholsteries, pillows and toys. This article focuses on manufacture of creamed natural rubber latex at cottage level and production of latex foam using the creamed latex as a step towards enhancing the income of especially the rubber smallholders.

Natural rubber latex

NR latex is obtained by tapping the natural species "*Hevea brasiliensis"*. Being a natural product, the composition of NR depends on many factors such as clone, soil conditions, tapping method and frequency age of the tree, *etc*. Hevea latex contains about 60% water, 25-35% rubber hydrocarbon (cis1,4 polyisoprene) and 4-5% non-rubber constituents. The main non-rubbers present are proteins, lipids, carbohydrates, metal ions and inorganic ions. Density of fresh NR latex is around 0.98 g/cm^3 and pH is in the range 6.5-7.0. There are three particulate components suspended in the aqueous medium, namely rubber particles (the main particulate component), lutoid particles and Frey-Wyssling particles. Rubber particles are protected by a complex film containing proteins and lipids. Rubber hydrocarbons in a rubber particle are non-water soluble and occur as molecular aggregates. The rubber particles are usually spherical with diameters ranging from about 0.02 to 3 µm. The most abundant non-rubber particles are the lutoids. These are spherical in shape and typically 2-5 µm in diameter and are heavier than rubber particles. Frey-Wyssling particles are also spherical and often bright yellow in colour due to the presence of carotenoid pigments. They are larger in size (4-6 μm in diameter) and have a slightly higher density than rubber particles (Jacob *et al*., 1993).

The fresh NR latex obtained from rubber trees is not stable during storage and transportation due to the presence of a higher amount of non-rubbers. Also, it is not economical to produce latex based products from fresh NR latex due to the high water content. Therefore, fresh NR latex has to be processed to manufacture finished latex based products. The initial processing operations are preservation and concentration. To prevent spontaneous coagulation and putrefaction, preservatives are added into the field latex (Ho, 2013). These preservatives destroy and deactivate micro-organisms and enhance colloidal stability of rubber particles. The most widely used short term preservative or anti-coagulant is ammonia. Concentration of ammonia should be 0.6-1.0 % by weight of latex for high ammonia concentrated latex. Although ammonia is the most effective preservative for latex, it has disadvantages especially the pungent odour. Therefore a low concentration of ammonia is used with other chemicals such as tetramethylthiuram disulfide (TMTD), zinc oxide (ZnO) and lauric acid during manufacture of low ammonia concentrated latex and these are known as secondary preservatives.

Concentration of NR latex

The process of latex concentration involves the removal of a substantial quantity of water from fresh NR latex. Concentrated latex can be produced from field latex using creaming, centrifuging, electro-decantation and evaporation processes. Evaporation involves only removal of water. Other three processes involve partial removal of non-rubber constituents and smaller rubber particles. Therefore, particle size range is reduced and high degree of purity is obtained. Out of the above four latex concentration processes, centrifuging and creaming are the processes commercially used.

Creaming process

Creaming is a chemical process. It involves the addition of creaming agents into the vessel containing field latex to speed up phase separation. In the mechanism of creaming, a loose network between molecules of creaming agent is formed and rubber particles adhere to this network. As a result, the Brownian motion is suppressed and serum and rubber particles in the fresh NR latex are separated. The lighter rubber particles move to the top phase and serum to the bottom phase. However, the loose network is not distributed uniformly throughout the latex and hence, motion of some latex particles is taken place. These particles are entrapped in a network and a cluster of particles is formed. These clusters grow by the continuous entrapping of particles and finally break free from the network and move upwards through the aqueous phase. The creaming rate and the rubber content of the creamed latex are important parameters for rubber technologists. Efficiency of creaming of field latex depends on number of factors such as velocity of the rubber particles, density of the serum and rubber particles, radius of the rubber particles, concentration of creaming agent, age of the latex, temperature of the latex, alkalinity of the latex, soap and stirring time of latex with creaming agent. Creaming of latex can be increased by increasing the rubber particle size. The speed of creaming of latex can also be increased by increasing the difference between densities of rubber particles and serum. Further creaming can be increased, if the viscosity of the serum is lower (Blackley, 1997).

Preparation of concentrated latex according to the creaming process

Field latex is collected and preserved with 0.6% (w/w%) ammonia. Magnesium content of field latex should be brought down to 80-100 ppm level by adding the calculated amount of DAHP and keeping undisturbed for 24 hours. The sludge is separated from latex by filtration. Creamed latex is prepared using the formulation given in Table 1 according to the process flow chart shown in Figure 1. After removal of sludge, 70% ammonium oleate is added into the treated latex. The mixture is thoroughly stirred at a speed of 120 rpm for 10 min. before incorporation of the creaming agent. Thereafter the creaming agent, carboxy methyl cellulose is added into the above latex mixture and agitation is continuously performed for another 30 min. Finally latex mixture is transferred to the creaming unit (Fig. 2) and it is kept at room temperature for 1-2 weeks.

Table 1. *Formulation suitable to prepare creamed latex*

Ingredient	Quantity (phr)
Field latex (30-35% DRC)	100
Ammonium oleate [70 % (w/w%) in water]	1.5
Carboxy methyl cellulose [2 % (w/w %) in water]	0.29

Collect and preserve the field latex with 0.7 % ammonia (w/w)

⇩

Add DAHP and keep for 24 hours
(If Mg^{2+} ion content in the latex is more than 100 ppm)

⇩

Filter the latex and remove the sludge

⇩

Add 70% ammonium oleate to the latex and agitate at 120 rpm for 10 min.

⇩

Add 2% carboxy methyl cellulose to the latex and agitate at 120 rpm for 30 min.

⇩

Transfer the latex mixture to the creaming unit and keep for 1-2 weeks

Fig. 1. Process flow chart for manufacture of creamed latex

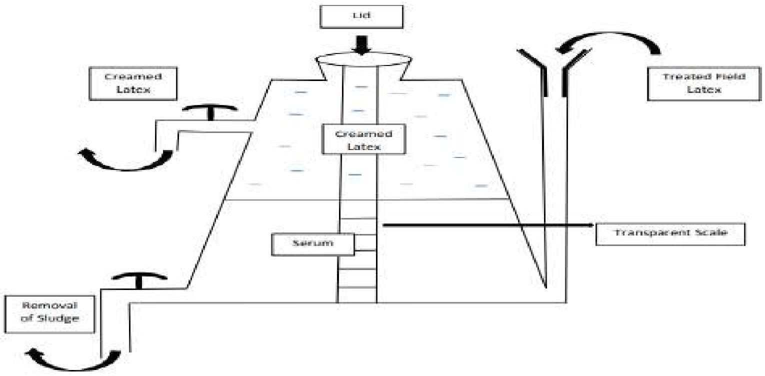

Fig. 2. Creaming unit suitable to manufacture creamed latex at cottage level

Properties of creamed latex

The main parameters of the creamed latex produced, which are essential to be maintained to ensure the concentrate quality are, Dry Rubber Content (DRC), Total Solids Content (TSC), Mechanical Stability Time (MST), Volatile Fatty Acid No. (VFA No.), Potassium Hydroxide No. (KOH No.) and Ammonia Content (alkalinity). DRC of the creamed latex reaches 60% at the end of the creaming process. Achieving a 60% DRC level depends on the initial DRC value of the field latex. TSC is an indication of the total dry material as a percentage by weight in a latex sample. It includes the residues of externally added materials during the processing of latex. TSC of creamed latex is about 62-63%. Mechanical stability indicates the stability of the latex concentrate to mechanical shear forces. This is the most important parameter to determine the quality of the final product. MST of creamed latex should be within 600-1200 min. for it to be suitable for manufacture of finished products. Another very important parameter for the concentrated latex is VFA No. VFA No. is recommended to be less than 0.03 for creamed latex. Early ammonia addition to the field latex is recommended to minimize the increase of VFA content. KOH No. is the measure of the ionic strength of the serum in the presence of ammonia. Therefore, if latex is bacterially degraded, ionic strength and hence KOH No. increases. Poorly preserved latex will have a high KOH No., but a high KOH No. does not necessarily indicate a poorly preserved concentrate. The favourable value of KOH No. for creamed latex is 1%. Alkalinity indicates ammonia level of the latex. Alkalinity of the creamed latex produced could reduce gradually due to evaporation during storage and possible reaction with other substances. Alkalinity of creamed latex should be 0.2%. Presence of Mg^{2+} ions in latex normally leads to spontaneous coagulation.

Advantages and disadvantages of creamed latex

DRC is higher and the difference between TSC and DRC is slightly smaller in creamed latex in comparison to centrifuged latex. KOH and VFA numbers of creamed latex are better and MST is higher than centrifuged latex (Yumae *et al.*, 2010). Creaming process is simple and easy to operate and initial capital cost is less. Labour cost, energy consumption and operation cost are low. The proportion of rubber lost in the skim is small and it is an environmental friendly process. Although, creaming of field latex is an effective way to concentrate field latex, there are some disadvantages. Creaming process is slow. Sensitivity to variation is during storage and transportation of creamed latex cannot be avoided. However, creamed latex can be stored for more than three months with proper preservation. Overall loss of the creaming process is greater than that of the centrifuging process. Chemical cost is high.

Manufacture of NR latex foam using creamed latex

NR latex foam produced out of NR latex is a soft and spongy material. It is durable, flexible and environmental friendly and exhibits hygienic properties. Dunlop method developed in the late 1920s is the most popular method for production of latex foam rubber products. Latex foam rubber produced in this method consists of open and interconnecting cells and has a porous surface skin, which allows air to pass through readily.

The Dunlop method as a batch process can be used to manufacture latex foam rubber at cottage level using creamed latex. Creamed latex is sieved, measured and stirred using a mechanical stirrer for reduction of ammonia content to 0.1-0.2%, while stirring at about 50 rpm. Potassium oleate soap is added to minimize any risk of destabilization. Thereafter, sulphur (vulcanizing agent) and phenolic type antioxidant are added and stirred at 50 rpm. After 2 hours, accelerators ZMBT (zinc 2-mercaptobenzothiazole) and ZDC (zinc diethyl dithiocarbamate) are slowly added to the mixture. After mixing is completed, compound is matured for 12-16 hours at room temperature with continuous stirring at slow speed (50 rpm). After maturation of the compound, fillers (*e.g.* calcium carbonate) can also be added with continued stirring to maintain the physical properties of foam rubber and cost reduction. Next the matured compound is poured into the foam mixer, which consists of a bowl and a wire whisk stirrer. It is beaten until the volume is increased up to three times of the initial volume. The initial foaming is carried out at high speed and when the foam is approaching the final volume, the speed is reduced to medium rate. After the desired volume is obtained, foaming speed is lowered to obtain an even foam. Thereafter, DPG (diphenyl guanidine, secondary gelling agent) and zinc oxide (ZnO) are added and beating is continued for 1 min. Subsequently, 20% freshly prepared dispersion of sodium silicofiuoride (SSF) is added as the primary gelling agent and the foam is beaten for another 45 sec. Finally, the ungelled foam is quickly poured into a preheated aluminium mold and allowed to gel for about 4-5 min. at room temperature. The gelled foam is cured in a hot air oven at 100^{o}C for 1-2 hours. Cure time depends on product specifications. Once the foam is cured, it is removed from the mould and washed with deionized water to remove potassium oleate soap and excess unreacted chemicals. After washing, the cured foam is dried in a hot air oven at 80^{o}C for 8 hours. A formulation suitable to manufacture latex foam using creamed latex is shown in Table 2**.**

Table 2. *Formulation for manufacture of NR latex foam using creamed latex*

Ingredient	Wet weight (g)
Creamed latex	167
50% Sulphur dispersion	4
50% Antioxidant(phenolic) dispersion	2
20% Potassium oleate solution	8
50% ZDC dispersion	2
50% ZMBT dispersion	2
50% ZnO dispersion	10
33% DPG dispersion	2.9
12.5% SSF dispersion	7.9
50% Filler dispersion	as required

Gelling is one of the most important steps in latex foam manufacture. In the Dunlop process, gelling is achieved in a one-step operation using ZnO and sodium silicofluoride (SSF). Gelation occurs at a pH of 8-8.5. After the froth has been made by mechanical agitation of matured compounded latex, ZnO and SSF are added separately to the compound and SSF slowly hydrolyzes and brings latex to gelation. Gelation of latex takes place due to the formation of hydrofluoric acid (HF), which leads to reduction of pH, adsorptive effect of silicic acid and destabilization effect of zinc amines foamed from the reaction between zinc oxide and ammonium fluoride. The choice of suitable level of ZnO and SSF and in some instances DPG leads to destabilization of the air-liquid system and the rubber-liquid system can be controlled to give an open-cell foam. Gelling time is an important parameter in latex foam manufacture. To get the required shape of a latex foam product, foamed latex should properly flow inside the mould before gelling takes place. In general, the gelling time of pillows and mattresses is 2-4 min. and 5-10 min., respectively. For cottage level manufacture of latex foam products using foaming, curing and washing processes, a cake beater/foam mixer, small steam oven and house-hold washing machine, respectively can be employed. Sunlight can be used for drying of small foam rubber products. To find a good income from latex foam products manufactured at cottage level, easily marketable, attractive products with a high demand should be identified for production. These foam rubber products could be marketed through online marketing such as social media and web sites.

Properties of NR latex foam produced using creamed latex

Important physico-mechanical properties of foam rubber are density, hardness, compression set and shrinkage (Roslim *et al.*, 2012). All the above mentioned properties can be modified by adjusting the curing system, loading of foaming agent, DPG and SSF. Also, properties depend on the time of beating of latex foam compound. Fillers and natural fiber materials can also be incorporated to latex foam compounds to get desired properties.

Applications of NR latex foam produced at cottage level

Creamed latex can be used to manufacture latex foam products such as cushions and sheets for automotive and furniture applications, masks, toys, key tags and souvenirs, shoe arches, backings for rugs/carpets, facial prosthetics, *etc.* at cottage level.

Manufacture of NR latex foam using creamed latex produced at field level

Creamed latex was produced at field level using 20 liters of field latex (31% DRC) with the involvement of smallholders in Kalutara and Ratnapura districts according to the procedure employed for lab scale trials. Latex quality parameters of creamed latex produced was evaluated at the Rubber Research Institute of Sri Lanka (RRISL), Ratmalana laboratories and compared with those of centrifuged latex. DRC of 60% was obtained for creamed latex in 10 days of the creaming process carried out using the creaming unit developed by RRISL (Fig. 2). The level of pH of both creamed latex and centrifuged latex was around 10.5. Non-rubber content of creamed latex and centrifuged latex were 1.32 and 1.26, respectively. VFA No. of creamed latex and centrifuged latex were 0.026 and 0.020, respectively. Therefore, non-rubber content and VFA No. of creamed latex were more than those of centrifuged latex, probably due to the presence of residues of externally added materials during processing. MST of creamed latex and centrifuged latex were 870 and 600, respectively. High MST value of latex is an advantage in latex foam manufacturing process as otherwise the latex may coagulate during the foaming operation.

To optimize production of creamed latex, more creaming units should be used with continuous production and alkalinity of creamed latex should be maintained at 0.6-0.7% to control the VFA No. at a low level. If VFA No. of creamed latex is more than the maximum acceptable level, the latex cannot be used to produce latex foam. The failed batches of creamed latex could be blended with creamed latex of low VFA No. to get the required value of VFA for production of latex foam. If creamed latex with an ammonia content of 0.6-0.7% is stored in a sealed container, shelf-life of it would be more than three months.

Manufacture of latex foam products such as mattresses and pillows is not an easy task for smallholders as the moulds needed for the purpose are complex and fabrication of these moulds involves a high cost. Therefore, cushions for automotive and furniture applications were manufactured at RRISL, Ratmalana with creamed latex produced at field level as well as high ammonia centrifuged latex and properties were compared.

Gelling time of latex foam produced with centrifuged and creamed latex was around 5 min. Therefore, gelling time of both latex foams is at the industrially accepted level. Indentation Hardness Index of latex foam prepared with creamed and centrifuged latex was 9 N/m^2 and 5 N/m^2, respectively. Higher hardness of latex foam produced with creamed latex may be due to higher amount of non-rubbers present in it. Density of latex foam produced with creamed and centrifuged latex was 115 and 105 kgm^{-3}, respectively. Compression set of latex foam produced with creamed latex and centrifuged latex was 4.1 and 3.7%, respectively. In manufacture of latex foam, shrinkage is also an important property. Shrinkage of 10-20% is generally observed under normal conditions of production. Shrinkage of latex foam produced with creamed and centrifuged latex was 14.8 and 13.7, respectively. In overall, comparison of properties of latex foam indicates that centrifuged latex can be replaced with creamed latex to produce NR latex foam at field level.

Manufacture of NR latex foam using creamed latex is currently being carried out in Thailand by smallholders at individual level. The Rubber Authority of Thailand provides guidance to these smallholders with technical know-how to develop NR latex foam for various applications. The main purpose of writing this article is to encourage rubber smallholders in Sri Lanka also to engage in the production of creamed latex to manufacture NR latex foam for a wide range of applications. The capital investment required for operation of creaming and foaming processes to manufacture the above mentioned NR latex foam products at cottage level is low and the outcome would be an increase in the income of rubber smallholders for a comfortable living.

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