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Ground level impediments for proper adoption of rubber cultivation in Northern Province of Sri Lanka

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Abstract

The Government of Sri Lanka has taken a decision to expand the rubber cultivation to non-traditional areas with drier climates in the country. With the success of rubber cultivation in the Uva and Eastern Provinces, the Northern Province has been the next focus in the expansion process. Despite the evidence of having reasonable growth and acceptable climatic conditions in this region, rubber cultivation has only been successful in Vavuniya district. Therefore, the present study was conducted in Vavuniya, Mullaithivu and Kilinochchi districts in the Northern Province of Sri Lanka to identify possible socio economic, cultural and agronomic limitations affecting the adoption of rubber cultivation. Further, it was expected to identify farmer perceptions on the promotion of expansion process. All farmers with successful rubber cultivation in each district were selected along with similar numbers of unsuccessful farmers and farmers who are willing to cultivate rubber. Factors affecting the success of the rubber cultivation were determined using logistic regression method. Proficiency in Sinhala language, usage of mulch at early stage of rubber plants, affiliation to social organizations and availability of water source were identified as factors significantly contributed to the success of rubber cultivation. The study concludes that success of rubber cultivation in Northern Province of Sri Lanka depends mainly on communication efficiency between Sinhalese officers and Tamil farmers and usage of moisture conservation practices at the early stage of growth of rubber plants. Although many farmers failed in rubber cultivation, their perception on cultivating rubber is one of optimism, demanding organizational support for initial establishment. Involvement of government and non-government organizations and social interactions among farmer communities are required in such attempt.

Key words: adoption, agronomic, farmer perception, rubber, socioeconomic

Introduction

Rubber has become an essential commodity in day to day life with the increase in living standards of human. Having specific features, natural rubber (*Hevea brasiliensis* Muell Arg.) has been secured vital position in rubber industry providing renewable raw material for wide range of industries (Anon, 2016). Nevertheless, production of natural rubber has to be increased in order to cater the growing demand. Originally, cultivation of rubber was confined to wet tropics based on the specific agro-climatic requirements for optimum growth performance (Rao and Vijayakumar, 1992). However, many rubber growing countries have examined the posibility of expanding rubber cultivation to marginally dry non-traditional areas. Of them, some countires such as China, India, Vietnam, Thailand, Laos and Brazil have been able to establish rubber successfully under sub optimal climatic conditions (Chandrashekar *et al*., 1998; Fox and Castella, 2013; Priyadarshan *et al*., 2005).

The potential for expanding rubber cultivation to non-traditional drier areas has also been emphasized in Sri Lankan context too (Iqbal *et al*., 2010; Rodrigo *et al*., 2011a; 2012). First, rubber was introduced to the Intermediate zone of the country; *i.e.* Eastern Province and proven with satisfactory growth and yields (Rodrigo and Iqbal, 2009; Rodrigo *et al.*, 2014). Considering this success, Government of Sri Lanka (GoSL) has decided to extend the rubber cultivation to the drier climates in Northern Province. Rubber was established in Vavuniya, Kilinochchi and Mullaitivu districts of Northern Province, where similar agro climatic conditions are available. In this process, Rubber Research Institute of Sri Lanka (RRISL) and Rubber Development Department (RDD) were instrumental in providing technology required and subsidy payments (Rodrigo *et al.*, 2011b). Despite the evidence of having reasonable growth and acceptable climatic conditions in this region, rubber cultivation has only been successful in Vavuniya district (Iqbal *et al.*, 2016), raising doubts of any socio-economic and cultural impediments for the adoption of rubber cultivation in this region. With such background, the present study was aimed to identify any socio-economic, cultural and agronomic limitations associated with poor adoption of rubber cultivations in Northern Province of Sri Lanka.

Methodology

The study was conducted in Vavuniya, Kilinochchi and Mullaithivu districts where rubber cultivation has been initially targeted in the Northern Province of Sri Lanka. Farmers having successfully established rubber fields were the focal group for the study. Total number of farmers enabling to maintain successful rubber fields had been limited to 14; hence, the same was taken for information collection. For the comparison purpose, 20 farmers who failed in rubber cultivation were selected randomly from the same area. Further, similar number of farmers which have shown an interest on rubber cultivation were chosen randomly to identify their perceptions on new cultivation programme. A semi-structured questionnaire was used as the data collection tool. Information on socioeconomic, cultural and agronomic factors related to rubber cultivation were gathered. Socio-economic variables comprised demographic information of farmer and farm family, properties of the farm family, provision of technical and advisory services, issues related to land tenure, involvement in social organizations and financial situations such as income, expenditure and saving patterns. Under the cultural factors, farmer ethnicity and proficiency in languages were considered. Soil properties, water availability and experience on farming practices were considered under agronomic variables. Logistic Regression Method (LRM) and descriptive analytical methods were used to analyze quantitative and qualitative variables, respectively. Also non-programmed mathematical method was used to identify and rank farmer perceptions on rubber cultivation. In that, responses of rubber farmers were put into a Likert scale and then converted to numerical values. Data analyses were conducted using SAS statistical software.

Results

Contribution of socioeconomic, cultural and agronomic parameters to the success of rubber cultivation

Socio-economic and cultural parameters

Socio-economic variables showed no any significant difference between farmers having successful and unsuccessful rubber fields. Farmers were in the age range of 32 to 74 years with the average of 50 years. Most families were male headed (85%) and consisted with average of four members. Majority of them (70%) were educated only up to secondary level or remained below. On average, a family owned *ca.* 4.8 and 1.5 hectares upland and lowland extents, respectively. The greater number of farmers (70%) have not attended any other occupation than farming. They had farming experience of *ca.* 25 years, however none of their offspring engaged in farming activities. On average, farmers have been used to hire three labourers to assist farming activities of a hectare of land throughout at a cost of LKR 1,200 per labourer per day (Table 1).

Being newly introduced crop to the area, rubber farmers were mainly supported by RRISL and RDD in commencement of rubber cultivation. Almost all the farmers (97%) have accessibility for agricultural credit facilities, therefore many of them were able to carry out their farming activities without much suffering from financial difficulties. Irrespective to the outcome in rubber cultivation, 70% of farmers were willing to plant rubber again.

Total monthly income of a farmer household varied between LKR 15,000 to LKR 617,000 with the average value of LKR 175,000. Income received from the sales of farm products had been the main income contributor (65%) to this amount. On average, expenditure of a farmer household was LKR 135,000 per month; however, 60% of that was for the expenses of farming activities whilst the rest for household expenses. Therefore, farmers were able to save LKR 1,800 to LKR 120,000 per month (Table 1).

Table 1. *Socioeconomic background of farmers*

	Successful farmers		Unsuccessful farmers	
	Mean	**Range**	**Mean**	**Range**
Age of farmer (years)	49.7	36 - 68	51.7	32-74
Family size	4.6	3 - 8	3.7	1- 6
Farming experience (years)	26.4	7 - 45	23.8	10-40
Farm lands-upland (ha)	4.8	0.4 - 29	4.8	0.2-20.8
Farm lands-lowland (ha)	0.4	0 -1.45	2.5	0 to 21
Family labour	1.0	0 to 2	1.0	0 to 2
Hired labour per hectare per day	3.14	0 to 10	3.00	0 to 10
Monthly total income (LKR)	193,214	40,000-617,000	149,839	15,000-600,000
Monthly income from farming (LKR)	103,785	20,000-480,000	120,938	15,000-600,000
Monthly total expenditure (LKR)	151,321	38,000-603,500	115,060	13,200-505,000
Monthly expenditure for farming (LKR)	58,678	8,500-290,000	84,960	1,200-480,000
Monthly expenditure for household (LKR)	29,357	15,000-65,000	24,950	12,000-48,000
Monthly Savings (LKR)	41,892	2,000-120,000	34,779	1,800-110,000

Majority of farmers (74%) considered for the study have been confined to Vavuniya district whilst others represented Kilinochchi and Mullaitivu Districts. Of the total, 65% was Sinhalese and the rest were Tamils with no fluency in Sinhala language. Being in the Sinhalese ethnic group and fluency in Sinhala language were identified as factors that have significantly contributed to the successful establishment of rubber in this area. Further, formation of social organizations was observed as a common practice among Sinhalese farmers and it has significantly contributed for the success in rubber cultivation (Table 2). However, no traditional criticisms or believes on rubber cultivation were prevailed among both ethnic groups.

Table 2. *Summary of statistical (logistic regression) analysis for cultural parameters significantly contributed to the success of rubber cultivation in Northern Province of Sri Lanka*

Cultural parameters	Number of farmers (%)	Pr > ChiSq
Language skills (proficiency in Sinhala)		
Yes	22 (65)	0.0145*
No	12 (35)	
Ethnicity		
Sinhala	22 (65)	0.0145*
Tamil	12 (35)	
Membership of social organization		
Yes	23 (68)	0.0011*
No	11 (32)	

* at 5% significance level

Agronomic parameters

Farmers had shown more interest towards cultivating seasonal crops in Maha (major) season whist maintaining perennials in Yala (minor) season. They have used both own and hired farm implements for field activities. Agro-wells were the major water source (71%) for irrigating farm lands and access to an agro-well has significantly contributed to the success of rubber cultivation (Table 3). Common water canals have been used as an alternative approach where agro-wells were lacking. Only 68% of farmers were able to afford for water pumps to support in irrigating activities whilst the rest have used to divert canal water by making leader drains towards the farm lands. The surface irrigation method was the most popular irrigation method (91%) practiced by farmers; however, few used high tech irrigation such as sprinkler and drip systems. As a moisture conservation practice 56% of farmers had used mulch application around young rubber plants which significantly contributed to the success of rubber cultivation in this area (Table 3).

Table 3. *Summary of statistical (logistic regression) analysis for agronomic parameters significantly contributed to the success of rubber cultivation in Northern Province of Sri Lanka*

Agronomic parameters	Number of farmers (%)	Pr > ChiSq
Water source		
Agro well	24 (71)	0.0366*
Irrigation cannel	10 (29)	
Mulch usage for rubber plants		
Yes	19 (56)	0.0029*
No	15 (44)	

* at 5% significance level

Quantification of the contribution of key factors on the success of rubber cultivation

As per the linear regression analyses, success of the rubber cultivation has been mainly governed by two factors, *i.e.* proficiency in Sinhala language of the farmer and usage of mulch as a moisture conservation method at early stage of growth (Model 1). Other factors which were individually became significant at non-parametric logistic regression, were not strong enough to contribute the regression a model. Accordingly, proficiency in Sinhala language affect the success of rubber by 1.3 times whist usage of mulch as a moisture conservation method at early stage of growth by 1.7 times. (If the estimate is positive (above zero), then farmers are likely to be successful in rubber cultivation.

Success of rubber cultivation = -1.5552 + 1.3188 (proficiency in Sinhala language) + 1.6585 (Mulch usage at early stage of growth)

Model 1. Linear regression model fitted to quantify the effect of key factors affecting the success of rubber cultivation. Farmers proficient in Sinhala language and those who used mulch at early stage of growth were coded as ‘1’ whilst those not as ‘0’

Farmer perception on rubber cultivation

Farmers in all categories have highly been concerned on continuous and effective extension service, uninterrupted water supply, improved transportation system and introduction of suitable agronomic practices to enhance soil properties and moisture conservation. Farmers having successful rubber fields were expecting to have more lands to expand their cultivation whilst unsuccessful farmers were demanding quality planting materials, guidance from experienced rubber farmers and high tech irrigation systems to avoid any failures in subsequent attempts. Farmers who had no experience on rubber, have shown the interest to cultivate rubber in following seasons should subsidies and credit facilities be provided in addition to demands of rubber farmers mentioned above (Table 4).

Irrespective of the outcome of rubber cultivation, farmers in the area have been demanding institutional support from RDD and RRISL for the establishment of rubber in top priority (Table 5).

Table 4. *Farmer perception on agronomic and socio economic factors for rubber cultivation. (Ranks were given according to Likert Scale with the highest influenced factor shown by '1' and the lowest by '15')*

	Ranks		
	Successful farmers	**Unsuccessful farmers**	**Newly interested farmers**
Availability of extension services	1	4	2
Strength of farmer organization	10	9	10
Access of credit facilities	6	11	4
Access to advance technology	13	7	9
Availability of subsidies	14	13	11
Availability of skilled labors	8	10	12
Improved transportation facility	4	1	3
Availability of planting material	9	3	5
Availability of fertilizer	12	15	14
Uninterrupted water supply	2	2	1
Availability of farm land	7	8	13
Protection from wild animals	11	12	8
Awareness of diseases	15	14	15
Suitability of climate	5	6	6
Suitability of the soil condition	3	5	7

Table 5. *Farmer perception on institutional support given for rubber cultivation. (Ranks were given according to Likert Scale with the highest perceived support shown by '1' and the lowest by '6')*

	Ranks		
	Successful farmers	**Unsuccessful farmers**	**Newly interested farmers**
Neighboring farmers	5	4	5
Social groups	4	3	4
RRISL	2	1	2
RDD	1	2	1
Agriculture Department	3	5	3
Non-governmental organizations	6	6	6

Discussion

Despite the profitability and any other perceived benefits, introducing a crop to a new region is a challenge as it should fit not only with agro-climatic conditions but also with socio-cultural matrix of the local community. Moreover, farmers must be confident else are to be convinced on the compatibility of the particular crop with their desires. Initially, only risk seeking farmers adopt the technology and the rest would follow them after seeing the benefits. Rubber cultivation is considered to be profitable and proven to provide stable income to the peasant community (Rodrigo *et al.*, 2000). Nevertheless, introduction process of this crop to the Eastern Province of Sri Lanka took over 7 years to be buoyant in the farming community. In particular, attraction of farmers to this crop took place after seeing the latex tapping and financial benefits.

In Northern Province, rubber was introduced recently and farmers have never experienced its benefits as rubber trees are yet to be harvested. Therefore, it is acceptable to have low level of adoption in this region. Only risk seeking farmers would go for rubber at this stage and in order to accept any risk, farmers are to be economically sound. The present study has shown that income level of farmers in the Northern Province is reasonably high strengthening them to accept the risk. Some level of their risk seeking quality is further confirmed by their willingness to cultivate rubber. Even the farmers who failed in rubber cultivation in early attempts, have shown an interest to cultivate rubber again. Nevertheless, in accepting the risk, farmers expect additional outside support for cushioning any potential losses. Further, with the intervention of GoSL for establishing rubber through the government institutions, farmers would have realized the nature of supply driven approach. Hence their risk seeking approach is rather conditional and farmers expect all necessary supports to cultivate rubber. Moreover, lengthy payback period of rubber (Herath and Takeya, 2003) compared to the quicker returns from traditional short term crops, it is not surprising to observe such expectations of farmers in this region.

Obviously, water is a limiting factor for plant growth in dry regions. Being a crop originated from Amazon wet forests, water is more critical for rubber cultivation when grown in the Dry Zone. Therefore, water sources such as agro-wells and soil moisture conservation measures such as mulching have been the significant agronomic factors for successful rubber cultivation. Rubber is grown initially with traditional short-term crops as an intercropping system which water is irrigated to. Irrigation is not problematic at the beginning of dry season; however water availability for irrigation becomes limited towards end of the dry period. Therefore, soil moisture conservation measures is important for plant survival at this stage. This could be the reason for high level of significance in mulching for the success of rubber cultivation. This effect has been more prominent in model fitting in the quantification approach. Being not practiced, other soil moisture conservation methods such as silt/moisture pits and rain water harvesting ponds, have not been considered in this study. However, with the present evidence, introduction of such measures undoubtedly will play a positive role in successful cultivation of rubber in this region of the country.

In introduction process, technology transfer is the most essential element for the success. The technology is to be provided to make farmers knowledgeable and more convinced. Clarity of technology, attractiveness in expressions, friendliness and continuity in associations are essential to drive the farmers for the new crop. In such attempt, fluency in communication is a crucial factor. Officers of RRISL and RDD are mostly Sinhalese and not able to speak in Tamil. Communication barrier existed in establishing rubber with Tamil farmers as they could not speak and understand Sinhalese. Failures in rubber cultivation has mostly taken place among the farmers in the Tamil community reasoning out the significance in language and ethnicity factors in statistical analyses of this study. In particular, the proficiency in Sinhalese is one of the two determining factors of the model developed to assess the success of rubber cultivation.

It has been evident that social organizations play a positive role in introducing new technologies to stakeholders (Bebbington *et al*., 1994). Even in the present study, social organizations have been an important factor for rubber cultivation. These social organizations comprised farmers organizations, welfare societies, self-employers societies and were operative in Sinhalese dominated areas where rubber cultivation was successful. Such organizations encouraged farmers to be interactive hence facilitated to get sufficient knowledge and to be self-supportive for successful rubber cultivation.

In the model developed to quantify the effect of key parameters on the success of rubber cultivation, the proficiency in Sinhalese and mulching were the key driving factors. Positive output values show the potential for success with that farmers proficient in Sinhalese and apply mulch have the highest potential for successful rubber cultivation. Mulching has been more critical than the other due to the highly valued co-efficient. Even without being proficient in Sinhalese, a positive value is derived by the model if mulching is done. Though the potential level of success is low here with decimal product value, it indicates the level of importance in mulching in terms of conserving soil moisture.

The study guides the decision makers in the expansion process of rubber cultivation in the Northern region of Sri Lanka to identify the key governing factors, so that, future failures could be minimized. In agronomic activities, measures on soil moisture conservation should be in priority. Although proficiency in Sinhalese is important, it is rather difficult to educate the Tamil community in Sinhalese. Instead, Tamil speaking officers are to be employed to educate Tamil farmers in technology transfer process. Further, technology transfer should also be done through local affiliations (social organizations) to which farmers are attached.

Conclusion

Success of the rubber cultivation in Northern Province of Sri Lanka mainly depends on Sinhala language proficiency of farmers and usage of mulch as a moisture conservation practice at the establishment and early stage of growth of rubber plants. Further being a Sinhalese, a member of a social group and accession to a water source play significant role in successful establishment of rubber cultivation in the area. Although many farmers failed in rubber cultivation, their perceptions on cultivating rubber are still optimistic demanding organizational support at top priority.

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Impact of different latex harvesting systems adopted by some growers on economic performance

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Abstract

Due to higher thickness of bark shavings and excessive recovery tappings (RT), the crop losses and the percentage tapping panel dryness (TPD) of rubber plantations are very high. This has resulted in either uprooting of rubber trees before reaching the potential economic lifespan or maintaining them at uneconomical levels. Therefore, this study was carried out to determine the impact of different bark consumption (BC) rates associated with additional days of latex harvesting on yield and related parameters of rubber plantations in four estates (E1, E2, E3 and E4). An on-station experiment with five different harvesting systems, (i.e. T1 -S/2 d2 + rain guards (RG), T2 - S/2 d2 +3 RT per month, T3 - S/2 d2 + 5 RT per month, T4 - S/2 d3 + 2.5% Ethephon +RG and T5 - S/2 d1, was also tested with four rubber clones according to a split plot design with3 replicates in a 5.0 hectare field. Survey results revealed that the estates with management (E1 and E2) had a higher BC compared to well managed estates (E3 and E4). Intensive tapping systems and RT (T3 and T5) also led to significantly higher BC rates. It is estimated that high intensity (T3 and T5) tapping of the renewed panels will be consumed within 7-9 years, whilst those in normal tapping (T1 and T2) panels will be consumed normally within 10-12 years (potential lifespan). The higher number of RT and daily tappings would result in shortening of the economic lifespan of rubber trees with no significant increase in the yield per tree per tapping. More importantly, low frequency of harvesting (T4) will be extended the economic lifespan of both renewed panels more than 13 years with significantly higher yield per tree per tapping than the other harvesting systems.

Key words: bark consumption, harvesting systems, recovery tapping, rubber estates, yield

Introduction

Extending the economic lifespan through recommended latex harvesting systems and high quality tapping leads to increases in growers income whilst contributing to enhance national gross domestic production (Nugawela, 1995). Yield losses due to malpractices in harvesting could be minimized by utilizing the optimum harvesting period effectively which in turn will uplift the livelihood of latex harvesters and other sundry workers too (Silva *et al.*, 2012). Also, when the economic lifespan is extended, replanting could be delayed and hence causing minimum damage to the environment.

According to Nugawela (2001), the potential yield of each panel (from base/ground level to 120 cm height) should be exploited for at least 6 years under half spiral cut every other day, *i.e.*, S/2d2 tapping system. However, at present, in most commercial plantations, a panel is consumed within 3-4 years as a result of increasing tapping frequency with the objective of obtaining high yields (Silva *et al.*, 2012). In a situation like this, the estimated long term crop loss and the percentage of tapping panel dryness (TPD) are very high in rubber plantations (Nugawela, 1995; Senevirathna *et al.*, 2007). This has resulted in either uprooting of rubber trees before reaching the full economic lifespan or maintaining them at uneconomical levels (Silva *et al.*, 2012). Higher bark consumption rates also leads to harvesting of partially renewed bark. Under such situations, it is essential to study growth and yield related parameters in rubber trees. Being a commercial plantation crop, financial implications associated with different harvesting systems adopted by growers need to be assessed.

Therefore this study was aimed at determining the impact of different bark consumption rates associated with different latex harvesting systems on growth, yield and some yield determining parameters of rubber plantations.

Materials and Methods

This study was conducted as an on station field experiment and also as a survey in the field. A five hectare rubber field planted in 1999 at Rubber Research Institute of Sri Lanka (RRISL) sub-station, Kuruwita, in Ratnapura district was selected to conduct the on station experiment. This field consists of four rubber clones, *i.e.*, RRIC 100, RRIC 102, RRIC 121 and RRIC 133. Five different harvesting system, *i.e.* T1 -S/2 d2 + rain guards (RG), T2 - S/2 d2 +3 Recovery Tappings (RT) per month, T3 - S/2 d2 + 5 RT per month, T4 - S/2 d3 + 2.5% Ethephon + RG, T5 - S/2 d1, were tested in all four rubber clones using a split plot design with 3 replicates.

Initial field establishment including five treatments were laid as main plots (*ca*. 75 trees) whilst clones were taken as sub plots (*ca.* 15 trees) in October 2013. Before introducing the treatments, initial growth and bark thickness were measured. Pretreatment yield measurements were also obtained till end of March 2014 adopting conventional tapping system, *i.e.* S/2 d2 in the plots demarcated. Subsequently, tapping treatments were introduced and latex yields in terms of volume, dry rubber content (DRC) and yield per tree per tapping were taken. Tree girth, bark thickness and the thickness of the shaved bark were also taken at six months intervals. Assessments on wounds, tapping panel dryness and bark deformation on tapping panels were also done. Data of each variable was analyzed using analysis of variance procedure.

Using four different estates, *i.e.* E1, E2, E3 and E4 selected from two Regional Plantation Companies a preliminary field survey was done to assess the situation of bark consumption rates and panel position with respect to the age in each rubber field selected. In a tapping block of a field 10 percent of trees selected randomly were used to take measurements on bark depth, consumption, depth of tapping, angle of tapping and incidences of tapping panel dryness. According to the bark consumption rates, the relevant excess rates and the period for panels A and B (actual panel lives) to be consumed in different fields in each estate were estimated.

Results and Discussion

The study reveals that in most of the rubber fields in both plantation companies selected, the bark had been consumed at a higher rate than recommended. Actual tapping period of A and B panels in most of the rubber fields in estatesE1, E2 and E3 were 6-8, 5-8 and 6-8 years, respectively (Figs. 1 & 2). However, in estate E4 it is in between 10-12 years and is substantially better when compared to other estates. It is apparent that, most of the fields in all four estates surveyed, A and B panels are consumed in less than the 12 years as recommended for d/2 frequency by the RRISL. The loss of tapping days due to the interference of rain results in huge monetary losses to the country (Nugawela and Tillekeratne, 2001). Widely adopted method of the planters to recover the crop loss is to tap the rubber trees continuously when weather conditions are favorable to do so. This tapping system leads to higher bark consumption rates, poor yield per tree per tapping and TPD levels high as 15-20% at 2-3 years after tapping (Senevirathna *et al.*, 2007). The reason for high TPD could be that the crop is harvested from a tree without giving sufficient time required to re-synthesize the latex prior to harvesting it again (Gomez, 1983; Priyadarshan, 2011). Also, undertaking of late tapping results in 25% loss of crop when compared to normal tapping (Silva *et al.*, 2001). The above approaches are not the appropriate remedies to maintain proper yield whilst sustaining the use of rubber bark during the economic lifespan of the plantation. In this situation, planters are compelled to maintain their fields uneconomically or otherwise uproot such fields before the completion of the recommended lifespan, *i.e.* 30 years. Main reason for low yield levels from C and D panels could be due to not giving sufficient time for bark to renewal and also due to high incidences of tapping panel dryness.

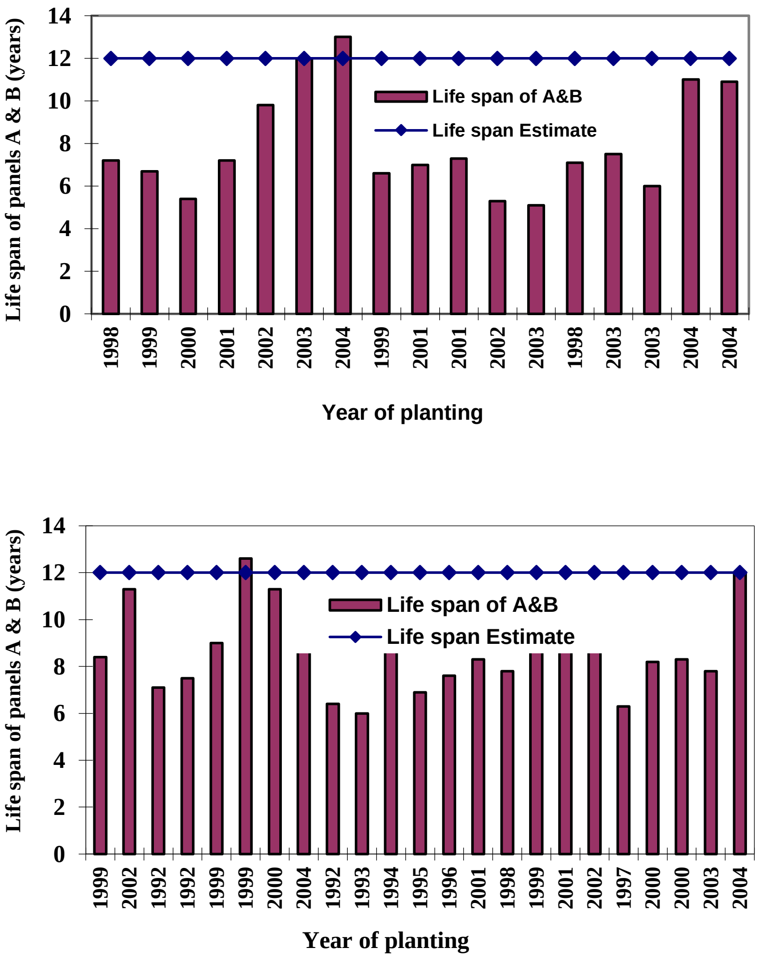

Fig. 1. Actual and recommended lifespans for panels A & B in different rubber fields indicated by year of planting in Estates E1 (above) and E2 (below). Horizontal line indicates the recommended lifespan to consume above panels

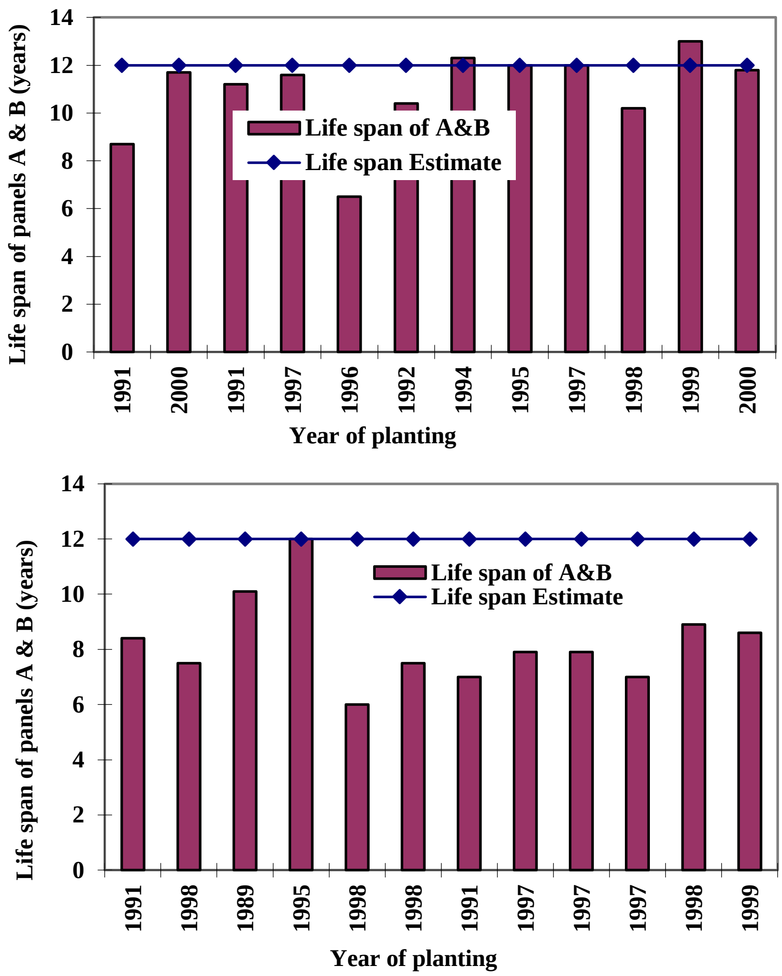

Fig. 2. Actual and recommended lifespans for panels A & B in different rubber fields indicated by year of planting in Estates E3 (above) and E4 (below). Horizontal line indicates the recommended lifespan to consume above panels

Findings of the on station experiment showed that the, tree girth, thickness of shaved bark and length of the tapping cut are not significantly different among the treatments indicating the distribution of trees among the treatments was comparable (Table 1). Further, the shaved thickness was also comparable since a single tapper was used to tap the trees in each and every sub plots. However, girth, thickness of the untapped bark and length of the tapping cut were significantly different ($p<0.05$) among the clones tested due to their inherent characteristics. The differences in the incidence of tapping panel dryness were significant ($p<0.05$) among the treatments (Table 2). Two treatments with recovery tappings, *i.e.* T2 and T3 recorded significantly higher TPD whilst T1 and T4 recorded lowest TPD. Treatment with daily tapping without rainguards, *i.e.* T5 recorded moderately high TPD level and it could be due to tapping rest in the wet days (Fig. 3). Hence, more number of recovery tappings might have resulted in high TPD incidence (Senevirathna *et al*., 2007 and Silva *et al*., 2001) in T2 and T3 as compared to T1 (conventional S/2 d2) and T4 (low frequency tapping). This study clearly showed that the rate of bark consumption was higher in T3 and T5 due to the excessive recovery tapping and daily tapping respectively (Fig. 4). Therefore, the estimated lifespan of panels A and B also would have been shorter significantly in such treatments (Fig. 5). Further, the excessive recovery tappings (T3) and daily tapping (T5) significantly reduced the economic lifespan of rubber trees whilst low frequency tapping (T4) significantly extended the economic lifespan of the rubber trees. On the other hand, low frequency harvesting system, *i.e*. S/2 d3 can increase the intake per tapper and increase the yield per unit of bark consumed (Nugawela, 2000 and Nugawela *et al*., 2000). It will reduce the cost of tapping further by enhancing the economic lifespan of the rubber tree. Also, low frequency harvesting is beneficial for the health of the high yielding rubber clones. However, the adoption of low frequency harvesting should be implemented based on socio-economic dimensions of larger and smaller rubber holdings (Chandy *et al*., 2013). It is evident that, excessive RT and daily tapping will result in shortening of the economic lifespan of the rubber plantations (Silva *et al*., 2001), without increasing crop harvested. As a result majority of rubber fields have become uneconomical units (Nugawela, 1995) especially with ad-hoc tapping of the bark using different cuts which are not of the same age, less drainage area and insufficient bark renewal (Silva *et al.*, 2012). To avoid adverse impact of high tapping frequencies, double cut alternative (DCA) tapping system has been introduced in other countries (Rukkun *et al*., 2012). However, long term investigation is required as some studies recorded comparatively higher TPD levels in DCA with stimulation than conventional low frequency harvesting.

Table 1. *Results of the different parameters studied under five treatments tested. Treatment means with the different superscripts in same row are statistically significant (p < 0.05)*

Parameter	Treatments tested					CV	P
	T1	T2	T3	T4	T5		
Mean girth (cm) at 150 cm	67.14[a]	70.33[a]	69.96[a]	68.51[a]	66.68[a]	6.59	0.2134
Bark thickness (mm) at 150 cm	7.11[b]	7.69[a]	7.44[ab]	7.17[b]	7.24[b]	5.46	0.3172
Thickness of the shaved bark (mm)	1.397[a]	1.393[a]	1.443[a]	1.438[a]	1.430[a]	8.13	0.7957
Length of the tapping cut (cm)	45.18[a]	48.39[a]	45.77[a]	45.84[a]	45.07[a]	9.28	0.4737

Table 2. *Results of some yield determining variables under five treatments tested. Treatment means with the different superscripts in same row are statistically significant (p < 0.05).*

Variable	Treatments tested					CV	P
	T1	T2	T3	T4	T5		
Bark consumption rate (cm/year)	22.64[c]	26.82[b]	29.16[a]	17.88[d]	27.14[b]	5.86	<0.0001
Yield per tree per tapping (g)	23.29[b]	22.77[b]	19.55[b]	28.62[a]	22.15[b]	13.26	0.0256
% TPD	22.02[cb]	33.24[a]	35.75[a]	17.87[c]	29.40[b,a]	43.44	0.0205
Estimated tapping duration of C & D panels in years (y) & months (m)	10y 7m	9y 0m	8y 3m	13y 5m	9y 0m		

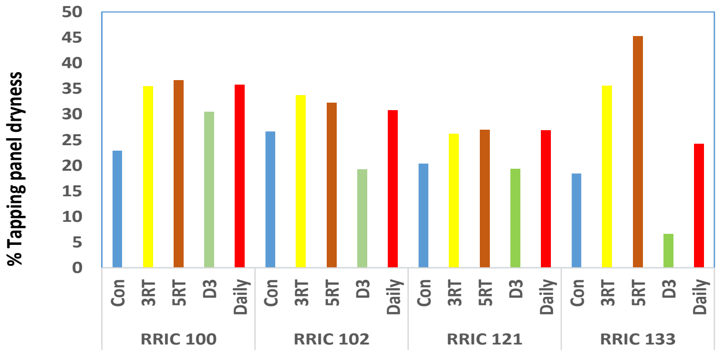

Fig. 3. Incidence of tapping panel dryness of different harvesting systems of different clones after three years

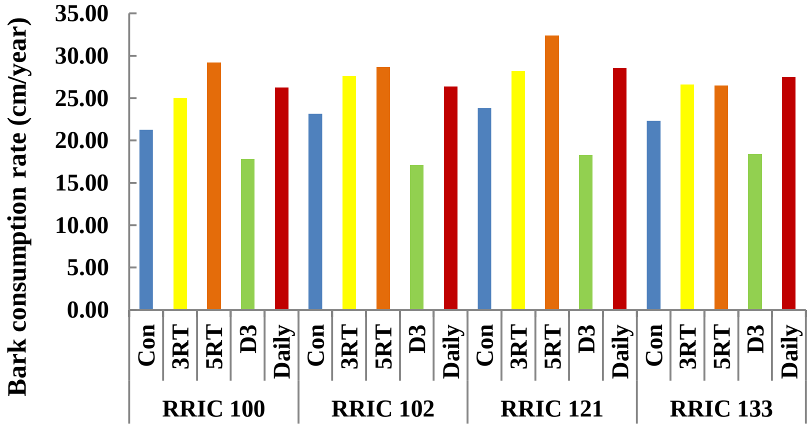

Fig. 4. Rate of the bark consumption of different harvesting systems of different clones

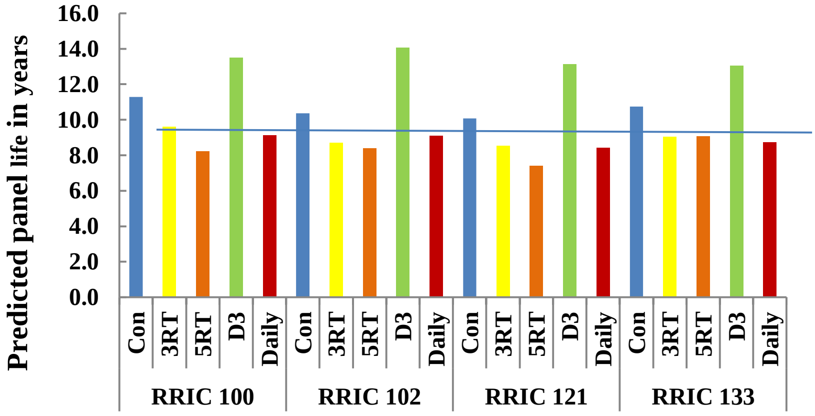

Fig. 5. Estimated panel lifespan according to the bark consumption rates of different treatments and clones

Conclusions

The results of the present study confirmed that over exploitation with excessive recovery tapping and daily tapping adversely influence on economic lifespan of rubber plantations without providing significantly high yields. This study also revealed that the incidence of TPD to be higher with over exploitation leading to a reduction of healthy trees in the plantation.

Acknowledgments

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Role of salicylic acid in irrigation scheduling for rubber nurseries in the Intermediate zone of Sri Lanka

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Abstract

Salicylic acid (SA)is an important signaling molecule known to alleviate the negative effects of drought stress in plants. The present study was conducted in a protected house at Moneragala substation of Rubber Research Institute of Sri Lanka to examine the possibility of using salicylic acid to minimize the net irrigation water requirement (NIR) of rubber nurseries in the Intermediate Zone of Sri Lanka which has the sub-optimal environmental condition for rubber. A split-plot design with the treatment combination of different soil moisture depletion levels of irrigationnamely10%, 30%, 50%, 70%, and 90%) and salicylic acid (0.5 mM) application frequencies (once in two weeks, once a month, once in three months and no application (control)). The effect of treatment combination was assessed on morphological and physiological growth attributes of seedling rubber plants. NIR was estimated based on maximum allowable depletion level, crop evapotranspiration (ET_c) and crop factor in irrigation scheduling.

Results revealed that the growth of nursery plants with irrigation at a 10% moisture depletion level was greater those. Moderate to severe water stress conditions were developed with the moisture levels at 50 to 90% moisture depletions respectively. The plants treated with 0.5 mM SA at monthly intervals have shown a higher growth when compared with bi-weekly or once in three months SA applications. Therefore, plants treated with 0.5 mM SA as monthly application at 50 % moisture depletion level exhibited higher tolerance to water stress compared to non-treated plants. Estimated NIR has shown that SA applications have had significant effect on lowering ET_c of rubber nursery plants and reduced the NIR of the rubber nursery by 25% of the total irrigation requirement.

***Key words**:* abiotic stress, drought tolerance, rubber and salicylic acid

Introduction

Water is one of the most essential substances for the existence of plant life. Water helps to dissolve nutrients in the soil solution which enables plant uptake. It is a reactant in many metabolic reactions in plant cells namely; photosynthesis, respiration and other enzymatic activities. Another important function of water is the thermoregulation, through the process called transpiration. In this process, a large amount of heat energy is released from the plant maintaining its temperature at a tolerable range (De Costa, 2001). Plant-water relationship is considered an important aspect in crop production under all types of climatic conditions. Therefore, a supplement of water from outside known as irrigation performs an important role in plant growth and development. A sufficient amount of rainfall supports agricultural crop production throughout the year. In many areas in wet zone of the country, receive an adequate amount of rainfall for two growing seasons per year. However, irrigation is necessary to supply moisture for plants whenever the rainfall and soil water storage are insufficient for crop growth (Kramer, 1983).

The ideal annual rainfall for growing rubber is 1650 to 3000 m which should be evenly spread throughout the year (Yogaratnam, 2001). Therefore, rubber grows well in the Wet Zone. However, there is a potential to grow rubber under sub-optimal conditions in the Intermediate Zone and some parts of northern regions of Sri Lanka. When the annual variation of rainfall in the Intermediate Zone is considered, nearly 60% of the rainfall experiences during the North-East monsoon in a range of 1200 – 2500 mm. Rainfall received during South-West monsoon is less than 1000 mm and a lesser amount is received subsequent months from May to September. Therefore, the probability of occurrence of dry months in the Intermediate Zone from May to August every year is well defined. The effect of the drought depends on the duration and the severity of the drought (Wijesuriya *et al.*, 2010). The influence of long drought with severe growth reduction and longer immaturity periods of rubber plants as a results of long period have been reported by many researchers (Samarappuli *et al.*,1996, Vijayakumar *et al*., 1998 and Iqbal *et al.*, 2010).

Prolonged drought impairs many physiological and metabolic processes in plants, which may lead to reduced plant growth and development than any other abiotic stresses (Anosheh *et al*., 2012). Many recent research studies have reported that salicylic acid is an important signal molecule known to modulate plant responses to abiotic stresses such as drought, temperature stress, etc. Salicylic acid has an ability to confer stress tolerance in plants (Senaratna *et al*. 2000; Anosheh *et al.*, 2012 and Habibi, 2012). Results of recent research carried out in rubber nurseries revealed that the exogenous application of salicylic acid alleviates water stress in young plants while improving their growth attributes (Nakandala *et al.*, 2016). Since the government has decided to expand rubber cultivation into non-traditional areas, sustainable planting materials production has become very important. Irrigation is, therefore, a necessity in those drier areas to ensure high-quality and healthy plants. Since water has been a scarce resource and also to improve the water use efficiency in plants, it is very important to have proper water management practices with the selection of an appropriate irrigation method for rubber nurseries.

Hence, this present study aim to examine the possibility of using salicylic acid in irrigation scheduling to minimize the net water requirement for rubber nurseries in the Intermediate Zone of Sri Lanka as a novel approach of irrigation technology.

Materials and Methods

The experiment was designed under protected conditions at Substation of Rubber Research Institute of Sri Lanka which is located in Moneragala District (060 50/ 06//N Latitudes and 810 18/ 55//E Longitudes). It belongs to the agro-ecological region of the Intermediate zone, IL1c (Wijesuriya *et al*., 2010).

A young budding nursery having 1000 one-month-old seedling plants was established in the protected house at Moneragala substation. Plants were arranged in a split-plot design with 20 treatment combinations which replicated three times. The treatments were five soil moisture depletion levels (10%, 30%, 50%, 70%, and 90%) of irrigation and four salicylic application frequencies (*i.e.;* once in two weeks, once a month, once in three months and no application) arranged in main and sub-plots respectively. Salicylic acid at a concentration of 0.5mM was applied as soil drench application for each plant before the irrigation was done. Preliminary testing on texture, bulk density, field capacity (FC), permanent wilting point (PWP), moisture depletion level and net irrigation requirement were done as pretest to determine the characteristics of soil, used in preparation of poly seedling nursery.

Plant stem diameter at 1 cm from the base of the seedling was measured by using a digital venire caliper. Leaf chlorophyll content was measured by using a chlorophyll meter (SPAD 502DL Plus). The meter reads chlorophyll content by an index value [SPAD (soil-plant Analyses Development) value] that is proportional to the amount of chlorophyll content of leaves. Dry matter content of the stem, leaves, and roots were assessed at the bud grafting stage. Samples were oven-dried at 85 ^{0}C for 48 hours until reaching a constant weight. Dry weights of each five plants were recorded and shoot: root ratio were calculated accordingly.

The available soil moisture content in 10 cm depth of poly bags was measured daily using a theta probe (ΔT Model DL6) with an external moisture meter. Statistical analysis was done by the analysis of variances followed by a mean separation procedure and Duncan's Multiple Range Test (DMRT), at a probability level of 0.05. SAS statistical software package – version 9.0 (SAS Inc., USA) was used to analyze data.

Estimation of net irrigation requirement of rubber nursery

Daily rainfall, maximum and minimum temperatures, pan evaporation and wind velocity were recorded at the Meteorological station at Moneragala. Net irrigation requirement (NIR) of the rubber nursery was estimated by using following equations which determine available soil moisture content, crop evapo-transpiration (ET_c), reference evapo-transpiration (ET_0) and dependable rainfall of irrigation scheduling as described in FAO Irrigation and Drainage paper 56 (Allen *et al.*, 1998).

- ***Available soil moisture content (D)***

D = (FC-PWP).BD.h/100 (Eq. 1)

Where,
D = Avalable soil moisture content (cm)
FC = soil moisture % at field capacity
PWP = soil moisture % at permanent wilting point
BD = Bulk density of soil (gcm^{-3})
h = Root zone depth (cm)

- ***Crop evapo-transpiration (ET_c)***

ET_c = ETo x Kc (Eq.2)

Where,
ET_c - crop evapotranspiration (mm/day)
K_c - crop coefficient
ET_o - reference evapotranspiration (mm/day)

- ***Reference evapotranspiration (ETo)***

ET_0 has been calculated by using average pan evaporation data. Pan co-efficient (Kp) for the Class A pan was used to determine ETo as described in FAO Irrigation and Drainage paper 56 (Allen *et al.*, 1998).

ET_0 = Epan x Kp (Eq.3)

Where,
ETo - reference evapotranspiration (mm/day)
Kp - pan coefficient (0.8)
Epan - pan evaporation (mm/day)

- ***Monthly dependable rainfall (DF)***

Monthly dependable rainfall was calculated by Weibull's method for a period of 15 years at a 75% expectancy level. The computation was carried out as described below:
The annual rainfall data set was arranged in the descending order of rainfall magnitudes. Data were ranked as, m = 1, 2, 3 up to the last record. Cumulative Probability (*P*) was determined by using the following equation (Eq. 4)

$$P = \frac{M}{N+1} \text{ x } 100 \qquad \text{(Eq. 4)}$$

Where,
M = rank number
N = total number of rainfall records

- ***Net irrigation requirement (NIR) of rubber nurseries***

NIR = ET_C – DF (Eq. 5)

Where,
NIR - Net irrigation requirement for a given month (mm/month)
DF - Effective rainfall for a given month (mm/month)
ET_c - Crop Evapotranspiration (mm/month)

Results

Soil moisture depletion pattern

Figure 1 illustrates the soil moisture depletion pattern for each depletion level at 10 cm depth of soil in the nursery plants one month before the salicylic acid application. Daily moisture measurements in the soils for a month were taken by using a Theta probe. The data were expressed as percentage of moisture availability in soil on volume basis and build up a moisture curve under each depletion level.

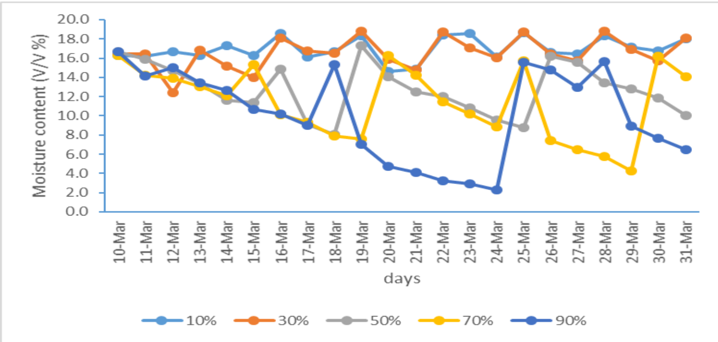

Fig. 1. Moisture curves at different soil moisture depletion levels

According to the result, soil moisture reached 17% when the soil was irrigated up to FC and it reached 4%, which was identified as the wilting point of seedling plants at higher depletion levels 70 to 90% (Fig. 1). Depletion levels also represent the intervals of irrigation scheduling. For example, at 30% depletion level, eight irrigations were carried out in a month with two-day intervals. Similarly, five- and four-times of irrigations were carried at 50 and 70% depletion levels with four to five days irrigation intervals, respectively (Fig. 1).

Growth responses of plants

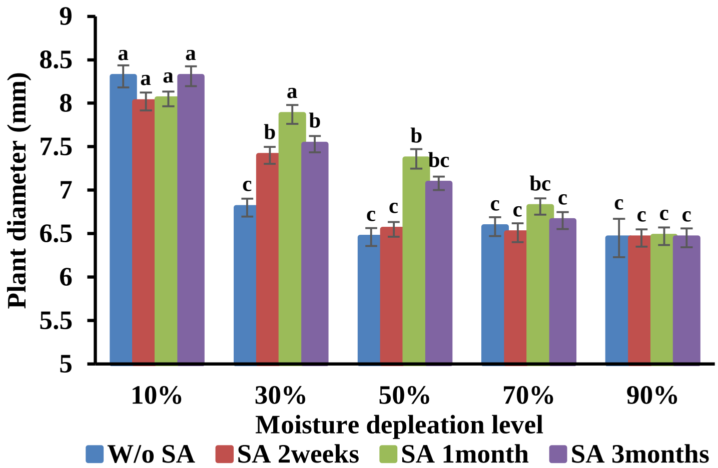

Fig. 2. The effect of frequency of application of salicylic acid (SA) under at different moisture depletion levels on plant stem diameter

The values are means and SE of n = 10 seedlings after 3 months of SA application for four months old seedling. Values followed by the same letter are not significantly different at (P≤0.05)

Treatments effect on plant stem diameter is depicted in Figure 2. Plants that were irrigated frequently at 10% depletion level indicate a higher growth ($p \leq 0.05$) irrespective of SA application. Plants that were irrigated at 30% depletion level and treated with SA at monthly intervals also showed a higher plant diameter ($p \leq 0.05$) compared with other SA application intervals and similar trend was also found at 50% depletion level. However, plants that were exposed to moisture stress at 70% to 90% depletion levels showed a notable decrease in stem diameter irrespective of the application of salicylic acid.

Leaf chlorophyll content

As shown in Figure 3, chlorophyll content is higher in the well-watered plants irrespective of SA applications. Leaf chlorophyll content reduced gradually with the increased of soil moisture depletion showing the highest reduction at 90% soil moisture depletion level. Moreover, a mild chlorosis was observed on the leaves when irrigated at 50 % depletion level and treated with salicylic acid at a monthly interval while acute chlorosis was observed in plants exposed to moisture stress at 70% and 90% depletion levels.

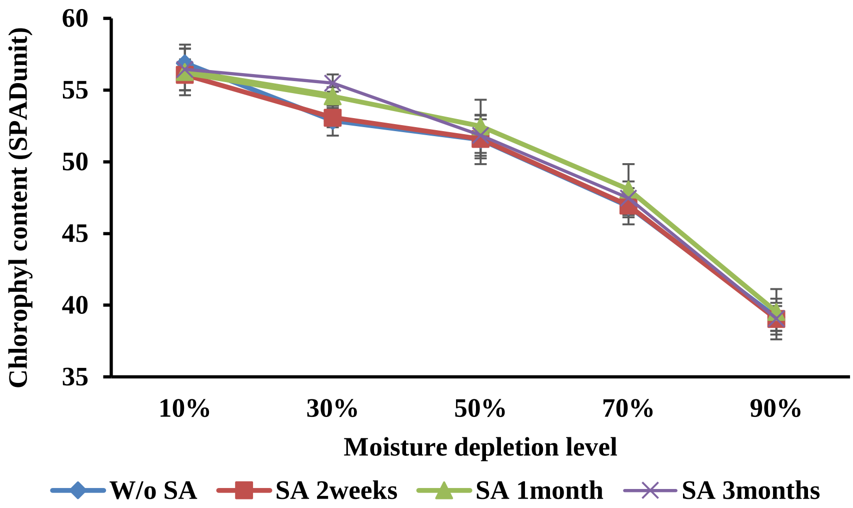

Fig. 3. The effect of frequency of application of salicylic acid (SA) at different moisture depletion levels on chlorophyll content of rubber seedlings

Dry matter content and shoot: Root ratio

There is a significant ($p \leq 0.05$) increase in total dry matter of plants when were irrigated at a 10% moisture depletion level irrespective of SA application frequency (Table 1). Regular irrigation at a 10% depletion level ensured 90% of soil water availability to plants which did not affect plant growth. Similarly, plants irrigated at 30% depletion level and SA application at two to four weeks intervals, also recorded a significant ($p \leq 0.05$) increment of dry matter content. Further, 30% depletion level and monthly application of SA showed a positive effect on shoot: root ratio (Table 1). In response to the 50% depletion level plants treated with SA at monthly intervals showed a significant ($p \leq 0.05$) increase in total dry mater content compared to the other application intervals (Table 1). Moreover, at 70% and 90% depletion levels, plants showed a significant ($p \leq 0.05$) reduction in dry matter accumulation irrespective of the frequency of SA application.

The overall results on plant growth indicated that, a 50 % depletion level of soil moisture, could be considered as the minimum level of soil moisture depletion that can be maintained with one-month interval of application of salicylic acid for saving of irrigation water during prominent dry periods prevailed in the Intermediate Zone of Sri Lanka.

Table 1. *Dry matter content and shoot: Root ratio*

Soil moisture depletion level	Frequency of salicylic acid application	Total dry weight (mg)	Shoot: root ratio
10%	Control (without SA application)	22.15±1.00[a]	4.17±0.56[a]
	Once in 2 weeks	21.15±1.26[a]	3.93±0.23[a]
	Once a month	20.91±0.94[a]	3.89±0.56[a]
	Once in 3 months	21.22±0.99[a]	4.10±0.18[a]
30%	Control (without SA application)	17.21±1.05[b]	2.66±0.15[b]
	Once in 2 weeks	19.92±0.98[a]	2.80±0.20[b]
	Once a month	17.21±1.25[b]	3.08±0.17[a]
	Once in 3 months	14.47±2.01[c]	2.41±0.59[c]
50%	Control (without SA application)	13.22±1.09[b]	3.70±0.27[a]
	Once in 2 weeks	14.79±2.40[b]	3.33±0.31[b]
	Once a month	16.00±1.87[a]	2.86±0.24[c]
	Once in 3 months	14.77±2.03[b]	3.03±0.30[b]
70%	Control (without SA application)	10.42±1.31[b]	3.33±0.09[a]
	Once in 2 weeks	11.04±0.94[a]	3.23±0.12[a]
	Once a month	10.45±1.00[b]	2.70±0.05[b]
	Once in 3 months	10.30±1.12[a]	3.03±0.08[b]

Soil moisture depletion level	Frequency of salicylic acid application	Total dry weight (mg)	Shoot: root ratio
90%	Control (without SA application)	8.48±1.07[b]	4.00±0.10[a]
	Once in 2 weeks	11.48±1.11[a]	3.70±0.09[a]
	Once a month	10.37±0.95[a]	3.85±0.97[a]
	Once in 3 months	10.53±0.98[a]	3.85±0.97[a]

The values are means and SE of n = 5 seedlings. Values followed by the same letter are not significantly different at ($P \leq 0.05$)

Estimation of net irrigation requirement for rubber nurseries

The above results highlighted that the monthly application of 0.5 mM salicylic acid as a soil drench at 50% depletion level enhances growth of rubber seedling plants when considered the stem diameter which is more importantly reveal at initiating bud grafting programme. With that, the crop water requirement of rubber nursery plants with SA application was estimated to scheduling the net irrigation water requirement (NIR) for rubber nurseries in the Intermediate Zone. For an effective irrigation scheduling in rubber nurseries, NIR was calculated by using derived equations as described in the methodology section.

Reference evapotranspiration (ET_0)

Reference evapotranspiration was estimated based on climatological data *i.e.;* pan evaporation, temperature, humidity, wind, *etc*. in the nursery site. Climatological data were obtained from the meteorological station located near the experimental site at a distance of about 100 m and estimation was done by using Eq.3 as described by Allen *et al*, (1998). ET_0 was calculated with a selection of pan coefficient (Kp) of 0.8 according to FAO Irrigation and Drainage paper 56 (Allen *et al.*, 1998) (Table 2).

Table 2. *Estimation of reference evapotranspiration (ET_0) on pan evaporation data*

Month	Pan evaporation (mm/day)	Pan Co-efficient (Kp)	ET_0 (mm/day)
January	2.94	0.8	2.35
February	3.76	0.8	3.01
March	4.26	0.8	3.41
April	3.38	0.8	2.70
May	4.13	0.8	3.30
June	4.51	0.8	3.61
July	4.37	0.8	3.50
August	4.55	0.8	3.64
September	4.36	0.8	3.49
October	3.31	0.8	2.65
November	2.49	0.8	1.99
December	2.74	0.8	2.19

Crop evapotranspiration (ET_c) rate with and without salicylic acid application

The crop evapotranspiration (ET_c) differs distinctly from the reference evapotranspiration (ET_o) as the ground cover, canopy properties and aerodynamic resistance of the crop are different from grass. The effects of characteristics that distinguish field crops from grass are integrated into the crop coefficient (K_c) (Allen *et al.*, 1998). In the crop coefficient approach, crop evapotranspiration is calculated by multiplying ET_o by K_c (Eq. 2). In the nursery condition of rubber nurseries at the Intermediate zone, estimated K_c values for rubber seedling plants were considered as 0.9 and 1.1 respective to with and without application of salicylic acid as a soil drench (Nakandala *et al.*, 2012). Monthly crop evapo-transpiration without and with the salicylic acid application was calculated accordingly and recorded in Table 3.

Table 3. *Monthly crop evapotranspiration (ET_c) of rubber plants with and without salicylic acid application*

Month	**ET_0 (mm/day)**	**ET_c without salicylic acid application (mm/day)**	**ET_c with salicylic acid application (mm/day)**	**ET_c without salicylic acid application (mm/month)**	**ET_c with salicylic acid application (mm/month)**
January	2.35	2.59	2.12	80.20	65.62
February	3.01	3.31	2.71	92.65	75.80
March	3.41	3.75	3.07	116.21	95.08
April	2.70	2.97	2.43	89.23	73.01
May	3.30	3.63	2.97	112.67	92.18
June	3.61	3.97	3.25	119.06	97.42
July	3.50	3.85	3.15	119.21	97.54
August	3.64	4.00	3.28	124.12	101.56
September	3.49	3.84	3.14	115.10	94.18
October	2.65	2.91	2.38	90.30	73.88
November	1.99	2.19	1.79	65.74	53.78
December	2.19	2.41	1.97	74.75	61.16
Total				**1,199.25**	**981.20**

Monthly dependable rainfall

Mean monthly dependable rainfall was computed by using the probability method (Eq. 4) for 15 years at a 75% expectancy level. Estimated values for monthly dependable rainfall at Moneragala is depicted in Figure 4.

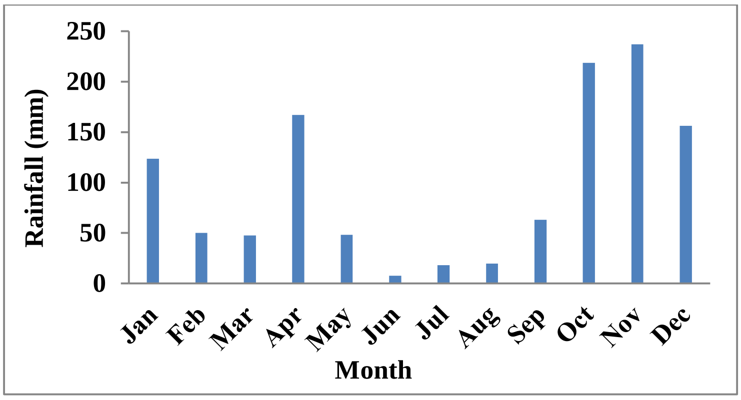

Fig. 4. *Monthly dependable rainfall*

As evident in Figure 4, monthly dependable rainfall varied from the maximum (237 mm) in November to the lowest (8 mm) in June. Only five months were seemed to have dependable rainfall exceeding the 100mm level (April, October to January). Remaining seven months are relatively dry and hence, plants should be irrigated for the better growth performances.

Net irrigation requirement of rubber nursery with salicylic acid application

Net irrigation requirement is the depth of irrigation water required to accomplish the crop water requirement or crop evapotranspiration (ET_c). As shown in Figure 5, irrigation is needed to fill the gap between precipitation and crop evapotranspiration during the dry months from February to September except for April. The results indicate that the net irrigation requirement was comparatively low in plants treated with a salicylic acid.

The net irrigation requirement (NIR) with and without salicylic acid application have been given in Table 4. It shows that NIRs for rubber nursery plants with and without salicylic acid application are 398.9 mm and 544.2 mm respectively. With that, the annual saving of irrigation water for the rubber nursery is about 145 mm per plant which is about 25%.

Table 4. *Net irrigation requirement (NIR) for the Rubber Nursery*

Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sept**	**Oct**	**Nov**	**Dec**	**Total**
Rainfall (mm)	123.60	50.00	47.7	167.20	48.20	7.70	18.20	19.80	63.20	218.70	237.00	156.4	1157.70
ET_c without salicylic acid application (mm)	80.20	92.65	116.21	89.23	112.67	119.06	119.21	124.12	115.1	90.3	65.74	74.75	1199.25
ET_c with salicylic acid application (mm)	65.62	75.80	95.08	73.01	92.18	97.42	97.54	101.56	94.18	73.88	53.78	61.16	981.20
Net irrigation requirement without salicylic acid application (mm)	0	42.65	68.51	0	64.47	111.36	101.01	104.32	51.9	0	0	0	544.22
Net irrigation requirement without salicylic acid application (mm)	0	25.80	47.38	0	43.98	89.72	79.34	81.76	30.98	0	0	0	398.96

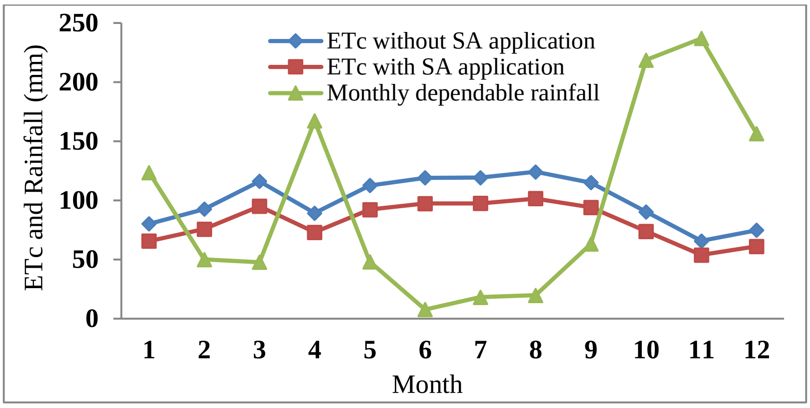

Fig. 5. *Dependable rainfall and crop ET*

Discussion

The results of the study indicates that the growth of rubber seedlings with irrigation at a 10% depletion level was greater than those to plants under water stress conditions. Moderate to severe water stress conditions were developed with the moisture levels at 50 to 90% depletions respectively. It is also evident that increasing the depletion level in the soil retarded the growth of seedling plants irrespective of the salicylic acid (SA) application (Fig. 2). Samarappuli (1992) also reported that the immature rubber plants which were grown at higher moisture depletion levels exhibit varying degrees of physiological and morphological impairments resulting in severe growth reduction and longer immaturity periods of rubber. However, results on the present study revealed that plants that were treated with 0.5 mM of salicylic acid at 50% moisture depletion level showed significantly ($p \leq 0.05$) higher growth performance than non-treated plants (Fig. 2).

Further, SA concentration at 0.5 mM applied at monthly intervals at 50% moisture depletion level enabled the rubber seedlings to maintain higher chlorophyll content compared to other treatments (Fig. 3). Leaf chlorophyll is a key component of the photosynthetic system that governs plant growth. Further, it found that the decrease in chlorophyll content was greater at higher soil moisture depletion levels *i.e.*; 70 and 90% irrespective of SA application. Similar observations were recorded by Singh and Usha (2003) for wheat seedlings.

It was found that plants treated with 0.5 mM of SA increased plant dry matter content by lessening the adverse effect of water stress at higher depletion levels. Gomez *et al.* (1993) also reported an improvement in plant biomass and yield of wheat genotypes under water stress with the application of salicylic acid.

Thus, these results highlighted that the moisture stress at higher soil moisture depletion levels decreases the plant growth severely and monthly application of 0.5 mM salicylic acid as a soil drench at 50% moisture depletion level enhances the plant growth performance by adjusting physiological processes of plants which are negatively affected by drought stress.

Meteorological calculations in Tables 3 and 4 have shown that SA application have had a significant effect on lowering ET_c of rubber nursery plants. These results indicate that the net irrigation water requirement of the rubber nursery was low with salicylic acid application. Further, it reveals that the saving of the net irrigation water requirement of the rubber nursery is about 25% of the total irrigation water requirements of the nursery.

Conclusion

In conclusion, irrigation with a monthly application of 0.5mM salicylic acid at 50% soil moisture depletion level of rubber nursery plants minimizes negative effects of drought stress and SA can be recommended to minimize the net irrigation water requirement of rubber nurseries in the Intermediate Zone of Sri Lanka.

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Effect of method of transplanting young budded plants on growth of rubber tree (*Hevea brasiliensis* Muell. Arg.)

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Abstract

Planting materials used for the establishment of new rubber fields in Sri Lanka are young buddings. At planting, it is recommended to remove the polythene bag fully. This is a high labour demanding exercise and has inherited shortcomings of lateral root systems getting damaged when making the vertical cut along the sidewall to remove the bag. Attempts were made to transplant the young budding plants with the bag and four other methods together with the currently recommended method as the control. Treatments tested were, planting with the whole bag intact, planting with the bag but without the base of the bag, four slits made on the sides of the base removed bag and with the whole bag intact and only four slits made on the sides of the bag. Two whorled young budding plants of clone RRIC 121 were used. The experiment was carried out according to a Complete Randomize Design (CRD). Each treatment had twenty replicates.

The growth data up to six years from planting revealed that girth values are not significantly different. The field establishment rates were 100% with all treatments. The labour requirement is low when the plants are transplanted with the bag, which guarantees that the root system is not disturbed or damaged and hence no casualties. Also, when large extents are planted it is extremely difficult to follow the correct step by step procedure to remove the polybag and a certain percentage of casualties are expected and reported. The differences in the growth and the timber volume were not significant among treatments 20 years after planting. It was found in this study that planting without the base of the polythene is equally effective as removing the whole bag.

Key words: field planting, *Hevea*, rubber, planting with the bag, RRIC 121, young buddings

Introduction

The extent under rubber (*Hevea brasiliensis* Muell. Arg.) is 130,000 ha (Anon, 2017) in Sri Lanka, and in order to maintain this area under the prevalent 30 year replanting cycle around three percent of this extent needs to be replanted annually. Accordingly, at a rate of 516 trees per hectare of land, about 2.2 million rubber plants are used and about 3,960 ha are expected to be replanted annually. In addition, new planting also takes place in non-traditional areas but to a lesser extent. Until the beginning of the 20th century, rubber tree was propagated with seeds and since the perfection of the bud grafting technique for rubber in 1917 by Van Helton, rubber plantations were established with bud-grafted plants raised in nurseries. Bud-grafted plants can be introduced to the field in various forms such as bare-root budded stumps, polybag plants young buddings, stumped buddings, *etc*. Since 2003, the recommended planting material for rubber is young buddings. In traditional rubber growing areas, seedling nurseries are established with the onset of seed fall in August and the young budding plants with two leaf whorls are ready for planting with the onset of the southwest monsoon rains in the following year which is the longest for those areas. In non-traditional rubber growing areas of the country such as in Moneragala and Ampara districts planting is done in October with Northeast monsoon rains.

The main advantage of using young budding in poly bags is the age of the plant, which is less than one year and, a well-established root system of young buddings which helps in the continuous growth in the field especially under unfavorable weather and climatic conditions. Also, the cost of young budded plants is comparable to bare-root budded stumps due to less nursery time involved in producing them. The high field establishment rate of young buddings is partially due to the well-established root system in the bag at planting. Uniform growth in the field is achieved mainly because of the vigorous culling of less vigorous plants and also due to less or no casualties in the field (Seneviratne and Nugawela, 1996).

Accordingly, one hundred percent success in field establishment and uniform growth of plants can be obtained if planted with the onset of the monsoon rains and with great care at planting by paying attention to every plant transplanted to the field. Preparation of the plants for field planting by tailing the taproot about 10 days before field planting date and minimizing watering during this period to keep the soil inside the bag hard which minimizes root disturbance. Though the establishment of rubber plantations with two whorled young buddings has proved advantages over bare-root budded stumps, in commercial plantations, casualties are reported due to dieback of the shoot. This happens when the root system is damaged and also the weather condition becomes dry soon after field planting. Hansethsuk (2003) has recommended fixing a split bamboo stick to the stem of the plant with leaves to prevent any damage from strong winds. It will prevent damages due to animals such as birds perching on the tender shoot. This is practiced by smallholder farmers in Sri Lanka too but very rarely in the estate sector.

The current recommendation for field establishment of young buddings is by removing the whole bag. The bottom of the poly bag is completely removed using a sharp knife and the bag along with the plant is then placed in the planting hole. A vertical cut is made starting from the bottom of the polythene bag, taking care not to damage the roots. Soil is filled up to that level and then the cut is continued up to the brim and the planting hole is filled with soil so that the cylinder of soil inside the polythene bag is undisturbed and the piece of polythene is carefully pulled out. Finally, the soil is packed firmly around the plant without pressing the soil core. As can be well understood, all these steps to safeguard the root system in the bag are not always adopted by the general workers who undertake this task of transplanting bag plants. Moreover, they are not aware of the importance of all these steps and they sometimes take the whole bag out before placing the plant inside the hole. Some recommendations such as keeping the soil in the bag dry are not possible in rainy weather. When the soil is soaked with water, damages to the roots is unavoidable. Having all the steps done carefully, one may press the soil around the plant with the foot which breaks or detach lateral roots. The whole purpose of having a good root system is lost under such conditions. However, if planting is done with the onset of the rains, the plant can withstand this until new roots are formed in 2-3 weeks. But, under unfavourable weather conditions, loss of water from plant tissues can affect the survival rate.

The objective of the study was to find out an effective and ergonomically viable method of transplanting young buddings safely to avoid casualties at planting while reducing the cost and preventing a set back on the growth.

Materials and Methods

Location and season

The experiment was carried out in one of the substations of the Rubber Research Institute of Sri Lanka, located at Nivithigalakale of Kaluthara district. Planting was carried out in May during the South West monsoon rainy season in 1999.

Planting materials

Young budding plants used for the study were of clone RRIC 121, grown up to two whorls in 7”x18” (15x45 cm), gauge 500, black polythene bags with bottom half perforated. Only plants with a harden top whorl were used. The tap root tailing was done using a pair of secateurs two weeks before planting.

Treatments

T1 - Planting with the poly bag intact
T2 - Planting with the bag of which base is removed
T3 - Planting with the bag of which base is removed (T2) and four slits made on the wall of the polybag with a sharp knife
T4 - Planting with the bag intact (T1) but four slits made on the wall of the polybag with a sharp knife
T5 - Whole bag removed (Current recommendation)

Method of planting and after care

The size of the planting holes was 2’x 2’x2½’ (60 x 60 x75 cm) and they were cut one month in advance, refilled and allowed to settle naturally. No fertilizer was incorporated to planting holes as recommended. Prior to planting a hole was dug using a mamoty to suit with the

height of the bag. The graft union was positioned 4-5 centimetres below the ground level.
All plants were inspected at weekly intervals for any mechanical damages or dying due to planting shock. Weeding and manuaring cycles were done according to the recommendation.

Experimental design and data collection

The experiment was carried out according to a Complete Randomize Design (CRD). Each treatment had twenty replicate plants.
Diameter values were measured at 6" (15 cm) above the graft union monthly during the first year using a Vernier calliper and they were converted to girth for comparison. After the first year girth was measured using a tape annually at 3' (90 cm) from the graft union throughout the experimental period.
Standard Error of Mean (SEM) was calculated for the monthly data collected and the annual girth data were analyzed using SAS Statistical package.

Estimation of timber volume

Tree diameter was calculated using girth values taken at the height of 1.5m using following equation.

$$D = {}^{G}/_{\pi}$$

Where,
D = Diameter of the tree (m) at the height of 1.5m
G = Girth of the tree (m)
π = constant

Total tree height was estimated using formula (1) (Munasinghe *et al.*, 2013).

$$TH_{wz} = -15.13 + 40.28 \Big/ \left(1 + \exp\left(-.13(YAP - 1.03)\right)\right) \quad \text{----------------} \quad (1)$$

Where,
TH_{wz}= Total tree height for Wet Zone (m)
YAP = Years after planting

Total timber log volume was estimated using formula (2) (Munasinghe *et al.*, 2013).

$$TV_{tt} = -0.02 + 0.394 * Diameter^2 * Height^2 \quad \text{------------------} \quad (2)$$

TV_{tt} = Total timber log volume (m^3)
Diameter = Diameter of the tree at the height of 1.5m (m)
Height = Estimated height using formula (1) (m)

Results

Field establishment rate recorded up to 12 months was 100% for all treatments. Shoot growth assessed by diameter measurements and converted to girth are given in Figure 1. Though the girth values for five treatments show differences, they are not significantly different. However, the treatments 1 and 4, those planted with the base of the bag and base plus slits made on the wall, respectively show slightly lower girth values in the first year after planting. But, the girth values of all treatments are in acceptable levels, more than 12 cm average girth at the end of 13 months.

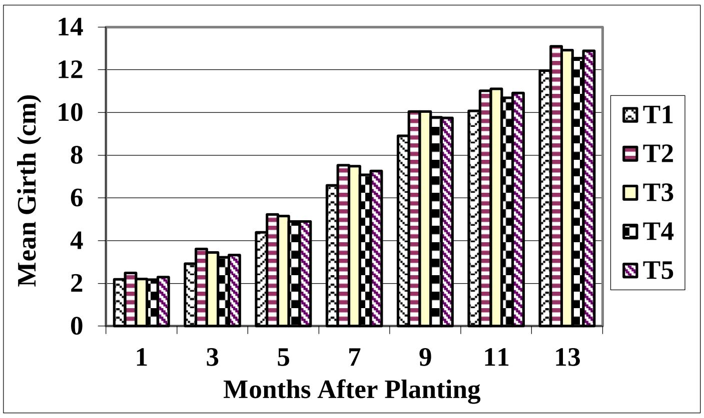

Fig. 1. Mean girth of plants measured at 6" (15 cm) above the graft union of the five treatments,

T1-Planting with the poly bag intact, T2-Planting with the bag of which base is removed, T3-Planting with the bag of which base is removed (T2) and four slits made on the wall of the polybag with a sharp knife, T4-Planting with the bag intact (T1) and four slits made on the wall of the polybag with a sharp knife and T5-Whole bag removed (Current recommendation).

Plants were not sampled to see the root growth, as there were only 20 replicate plants and also as the diameter or the girth was taken monthly during the first year and then annually to determine the growth. However, root growth of one of the plants planted with the bag without the base or any slits made on the wall (Treatment 2) is shown in Plate 1. This was taken after one year of field planting and by exposing the root system carefully from one side. Generally, the girth of the shoot and the tap root is similar and in Figure 2, collar region shows the girth of the taproot and the bag broken into strips when the tap root and the laterals grow.

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Fig. 2. Root growth of a plant planted with the bag but without the base or any slits made on the wall of the bag (Treatment 2) after one year of field planting

Mean annual girth (cm) of the young budded plants of five treatments up to six years of planting are given in Table 1. The lowest girth is shown by the plants planted with the base of the bag, throughout the first year followed by the plants planted with the base of the bag and the slits made on the wall. Though both treatments had the base of the bag intact, Treatment 4 had slits on the bag. However, the treatment effects had disappeared with the completion of one year after planting and hence the set back due to the presence of the bag seems temporary. The growth of the plant is partly determined by fertilizer absorption, which is the only important criterion.

Mean girth of the plants at the end of six years are shown in Figure 3. The lowest value of 51.4 cm was apparent in treatment planted with the base of the bag and with no slits cut.

Table 1. *Annual mean girth of plants of the five treatments*

Treatment	**Year after planting**					
	1	**2**	**3**	**4**	**5**	**6**
T1	11.90^{b}	16.22^{a}	20.88^{a}	34.60^{a}	46.00^{a}	51.54^{a}
T2	13.00^{a}	17.00^{a}	21.35^{a}	33.94^{a}	45.90^{a}	51.73^{a}
T3	12.90^{ab}	16.96^{a}	21.28^{a}	34.87^{a}	46.52^{a}	52.98^{a}
T4	12.50^{ab}	17.00^{a}	21.83^{a}	35.46^{a}	47.26^{a}	53.69^{a}
T5	12.80^{ab}	17.68^{a}	22.61^{a}	36.48^{a}	48.20^{a}	54.01^{a}

Means with same letter along the columns are not significantly different.

T1 - Planting with the poly bag intact, T2 - Planting with the bag of which base is removed, T3 - Planting with the bag of which base is removed (T2) and four slits made on the wall of the polybag with a sharp knife, T4 - Planting with the bag intact (T1) but four slits made on the wall of the polybag with a sharp knife and T5 - Whole bag removed (Current recommendation).

As it can be seen from Figure 3, variation within the treatment and among treatments is low in the girth and therefore, the differences are not significant among treatments. The annual girth increment (cm) of plants of five treatments are shown in Figure 4.

The timber volumes calculated based on the girth values taken after 20 years from planting are shown in Table 3. As it can be seen from Table 2, there is no significant difference among treatments for the volume of timber produced by the plants transplanted under different treatments.

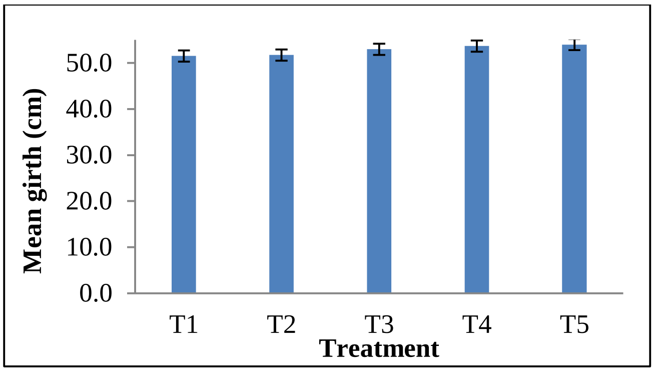

Fig. 3. Mean girth (cm) of the plants of the five treatments at the end of six years

T1 - Planting with the poly bag intact, T2 - Planting with the bag of which base is removed, T3 - Planting with the bag of which base is removed (T2) and four slits made on the wall of the polybag with a sharp knife, T4 - Planting with the bag intact (T1) but four slits made on the wall of the polybag with a sharp knife and T5 - Whole bag removed (Current recommendation). Bars show SEM values.

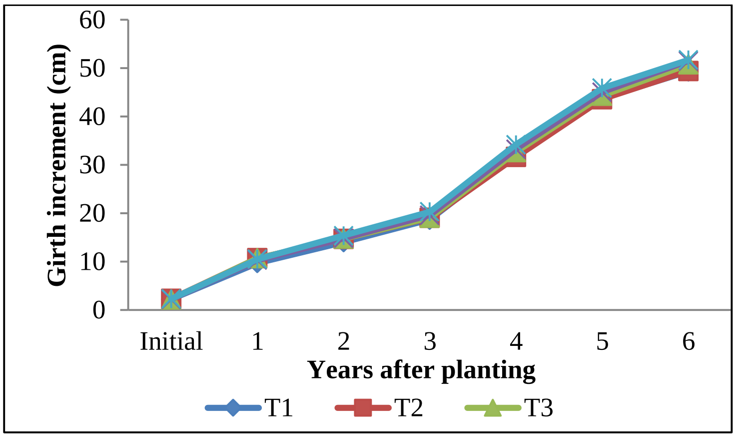

Fig. 4. Annual girth increment (cm) of the plants of five treatments

T1 - Planting with the poly bag intact, T2 - Planting with the bag of which base is removed, T3 - Planting with the bag of which base is removed (T2) and four slits made on the wall of the polybag with a sharp knife, T4 - Planting with the bag intact (T1) but four slits made on the wall of the polybag with a sharp knife and T5 - Whole bag removed (Current recommendation).

Table 3. *The timber volume calculated based on the girth values taken after 20 years of planting*

Treatment	Mean girth (cm)	Timber volume (m^3)
T1	78.39[a]	0.59[a]
T2	82.23[a]	0.64[a]
T3	81.60[a]	0.63[a]
T4	83.07[a]	0.66[a]
T5	80.32[a]	0.60[a]

T1 - Planting with the poly bag intact, T2 - Planting with the bag of which base is removed, T3 - Planting with the bag of which base is removed (T2) and four slits made on the wall of the polybag with a sharp knife, T4 - Planting with the bag intact (T1) but four slits made on the wall of the polybag with a sharp knife and T5 - Whole bag removed (Current recommendation).

Discussion

The root system of a plant is responsible for up-taking nutrients and water from the soil. Therefore, the growth and development of above-ground parts of a tree depend on the performance of the roots to a greater extent. The root architecture is important for perennial trees for anchorage when the tree is fully grown specially to withstand strong wind under heavy showers generally prevailing during monsoonal rainy periods.

The propagation of rubber is through bud grafted plants where the rootstock comes from a seed and the bud is from an authentic clone raised in a bud wood nursery for harvesting buds. A thorough selection process is adopted to select vigorous rootstocks for bud grafting, starting from collecting seeds from the early seed fall as the vigour of the root system has a key role to play in the growth of the scion (Anon, 2016/09). There is a significant positive correlation between the time taken for germination and the vigour of the plant and effective usage of the germination bed is therefore recommended for rubber nurseries. During field establishment, care must be taken not to disturb the root system, mainly not to introduce a set back to the growth of the plant. More importantly, if the roots are damaged in a plant with foliage on it, the plant often cannot survive due to the shock followed by dieback of the shoot. The extent to which the root system gets damaged during field establishment could influence the setback period, but it will soon grow roots when the plant has leaves which in turn produce and transport cytokinins to promote root growth. Similarly, when the plant has a profuse, vigorous, and undisturbed root system, it supports the growth of the areal part by absorbing water, nutrients and synthesizing auxins for the shoot growth.

The annual growth increment of young budded plants is generally 10 cm and rubber plantations are tapped after five years of planting. The requirement for a tree to be opened for tapping is 50 cm girth measured at 120 cm above the ground level or the graft union. However, growth rate depends mainly on the quality of the plants and the immature upkeep specially the application of fertilizer. Climatic conditions as well as microclimate, terrain and the soil condition too affect the growth of plants. The growth phase of budded plants is generally five years and the rate drastically reduces as the trees enter the mature phase where annual flowering and wintering is observed.

According to the diameter measurements of field planted plants, a significant difference among treatments could be observed only during the first year. The highest mean value given by T2, *i.e.*, plants transplanted without the base of the polybag, must be due to not getting the lateral roots disturbed during slitting of the bag in all treatments except for treatment 1 where the plants were transplanted with the bag intact. The lowest mean value given by T4, in which the plants were planted with the base of the bag intact and with only four slits on the bag can also be explained by the damage that occurs during making slits on the wall of the bag. When planting with the polybag intact, the lateral roots which generally grow geotropically, may find it difficult to penetrate the bag and thus take a little longer to start growing. But, all polybags had perforation at the bottom half of the bag and as seen in Figure 2, the lateral roots had naturally grown out from those holes though the base is blocked.

This could be a reason for the plants transplanted without the base to show a little higher girth during the initial months, though not significant. Another reason for the higher growth in plants transplanted with only the base removed could be that the lateral roots not getting damaged due to absence of slits on the wall. Generally, in young buddings when the stock plant is cut back after four weeks of the grafting date most of the lateral roots tend to die. This takes place to maintain correct shoot to root ratio (Dharmakeerthi *et al*., 2008). The size of the scion shoot depends on the food reserves of the rootstock. This statement is partly supported by the observation of bigger rootstocks given rise to thicker scion shoots (Seneviratne, *et al.*, 1996). However, as the scion shoot grows and develops further, the apex of the scion synthesizes auxins and is transported down to promote root growth as explained earlier. The increased root growth supports the scion to grow. The lateral roots inside the bag tends to form a network around the soil bole if kept in nurseries for a longer duration. Therefore, it is simply not possible to make a slit on the sidewall of the poly bag without harming at least part of the lateral roots, as there is no gap between the bag and the soil core (Fig. 5). Therefore, until the plant regenerates its lateral roots even with the recommended method of removing the bag. There will be a setback in the growth. The planting hole is 30” deep but the height of the bag is only 18” and therefore, inside the hole below the base of the bag the loose soil is available for the roots to start growing without any barrier when the base is removed as in treatments 2 and 4.

Fig. 5. The lateral root growth of young budding plants showing circular growth on the root bole.

The lowest mean girth values observed in plants transplanted with four slits on the sides could be again due to the damage to laterals. The growth of the taproot cannot be stopped by the layer of polythene of the base and only an aluminium sheet inserted to the base of the bag before soil filling could stop the penetration of the taproot which coiled inside at the base (Review of Plant Science Department, Annual Review 2001). As the taproot coiling at the base of the polythene bag often retards the growth of the seedling before bud grafting and also as it delays bud grafting unnecessarily, an experiment has been conducted to see whether the growth of the seedling improves if a central hole is made at the base of the bag in addition to the normally recommended perforation at the bottom half of the bag (Review of Plant Science Department, Annual Review 2001). As expected the growth was better and the morphology of the taproot was improved with no bending or coiling at the base before penetrating to the soil.

In the present experiment, any growth difference among treatments should gradually seize once the root growth starts. The data on the girth of the plants of different treatments is in accordance with the fact that once the roots grow out of the bag then the effect of the bag type, whether the base was present or whether the cuts were made on the sidewall would be immaterial.

Different methods practiced to transplant the bagged plants to the field can affect the growth and the morphological development of the root system and thus the growth of the whole plant. Rubber tree develops a strong taproot and extensive lateral roots. The whole root system accounts for about 15% of the total dry weight of a mature tree. It is reported that in three year old rubber trees the taproots are about 1.5 m long and the laterals about 6-9 m long (Priyadarshan, 2011). Growth of the main roots seem to regulate the development of the lateral branches of plant. Laterals are more numerous (Wightman and Thimann, 1980) and major lateral roots arise from the taproot and they grow in horizontal direction to the soil surface or grow slightly downwards. Laterals that arise at the bottom of the taproots do not extend horizontally as those nearer to the soil surface. The ultimate product of lateral roots is yellow-brownish, un-suberized feeder roots having around 1mm thickness. These roots are mainly responsible for the uptake of water and nutrients (Soong, 1976, Samarappuli *et al.*, 1996). It is found that feeder root density is significantly differs with the distance from the base of the rubber plant. The amount of feeder roots in the surface layer of soil is more than 75% of the total feeder roots.

The method of fertilizer application to rubber plants in the field is explained in the (Anon, 2016/4, Fertilizer to Rubber). Fertilizer is applied to four holes of 6-8” depth made around base of plant by forking. With the rain, the dissolved fertilizer is leached down and the feeder roots established there can absorb them. The establishment of the root system well below the ground level is advantages to protect the trees from wind damages when they are fully grown.

However, the development of a root system has a general pattern though it can be influenced by the soil type, mode of fertilizer application, soil moisture content and aeration, nature of the ground cover and cultivation practices, *etc.* Growth and distribution of the root system has a greater influence on nutrition and water uptake and thereby the yield of rubber tree providing a major pathway for the flow of nutrients. Root systems of young rubber plants are restricted to the soil environment within the polybag. After field establishment, they have the ability to develop and extend within the soil profile.

As observed in the present study, the method of transplanting the polybag plants can affect the growth of the root system, during the initial period until the new roots are generated. The girth or the growth of the areal part of the tree is the best indicator to assess the root growth and the nutrient uptake. Study reveals that planting with the bag with the base removed is so much ergonomically viable and also cost effective while guaranteeing no damage to the lateral roots in the bag.

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Development of Brown root disease in Sri Lankan rubber plantations: possible involvement of other tree species

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Abstract

Brown root disease caused by Phellinus noxius is becoming an important root disease of Sri Lankan rubber plantations. Hence, this study was conducted to identify the alternative host species of the pathogen and to determine the role of those species in the incidence and the severity of brown root disease in rubber plantations. Seventy brown root disease incidences were used to assess the host range and the disease transmitting pattern. A structured questionnaire was used to collect the background information from the growers and the extension officers. In association with the roots of the diseased rubber trees, roots/root pieces of twenty six alternative species were identified and pathogen was isolated from seven alternative species only. The signs and the symptoms of the collar and the root systems of rubber and the associated tree species were recorded. The pathogenicity of those cultures were proved by Koch's postulates and the seven different isolates showed cross infection ability among the species from which they were isolated and with rubber. The seven isolates showed a variation in their morphological and growth characteristics. It was observed that in all the brown root disease incidences on rubber, the primary inoculum was from a non-rubber species and the land had been previously either under the forest or abandoned for years with trees and shrubs of forest origin. With the findings of the study, it was concluded that the infection of brown root disease to rubber in these areas has an association with the other tree species such as Cereya arborea, Gmelina arborea and Bridelia retusa in the root contact.

Key words: brown root disease, forest-origin tree species, *Hevea brasiliensis*

Introduction

Brown root disease caused by *Phellinus noxius* is one of the important root disease of rubber plantations in Sri Lanka. *Phellinus noxius* (Corner) G. Cunn. is reported to be a widespread pathogen in tropical countries of Southeast Asia, Oceania, Central America, Caribbean, and Africa, where it causes brown root rot in a variety of trees of all ages and health conditions (Singh *et al.*, 1980; Bolland 1984; Hodges and

Tenorio 1984; Neil 1986, 1988; Nandris *et al.*, 1987; Arentz and Simpson 1989; Bolland *et al.*, 1989; Dennis 1992; CABI/EPPO 1997; Chang and Yang 1998; Larsen and Cobb-Poulle 1990; Ann *et al.*, 2002; Brooks 2002; Albrecht and Venette 2008). The name brown root rot refers to a brown to black mycelial crust formed by the fungus on the surface of infected roots and stem bases (Chang & Yang 1998). *Phellinus noxius* is placed under the family of Hymenochaetaceae within the Phylum Basidiomycota. It is characterized by its brown fruiting bodies with no clamp connections in its vegetative hyphae. However, *P. noxius* is generally considered a white rot fungus because of its ability to degrade lignin, a basic component of wood (Adaskaveg & Ogawa 1990, Chang & Yang 1998). Most of the species within the genus *Phellinus* act as saprotrophs in nature or as weak pathogens on trees. Only very few species are pathogenic with strong virulence, and *Phellinus noxius* is one of the strongest among them.

Brown root disease has a wide host range including, most of the economically-important plantation and other crop species such as, *Camellia sinensis* (tea), *Coffea* spp. (coffee), *Artocarpus altilis* (breadfruit), *Cinnamomum* spp. (cinnamon), *Theobroma cacao* (cocoa), *Cocos nucifera* (coconut), *Garcinia mangostana* (mangosteen), *Citrus* spp. (citrus), *Mangifera indica* (mango), *Artocarpus heterophyllus* (jack), *Tectona grandis* (teak) and *Swietenia mahogani* (mahogany). *Phellinus noxius* spreads by root contact and persists in roots and stumps of infected plants for more than 10 years even after the death of the host (Chang 1996). The economic impact of *P. noxius* is highly variable and a loss of up to 60% has been observed in some other rubber growing countries (Nandris *et al.*, 1987).

The rubber industry is now being extended to non-traditional rubber growing areas in *Uva*, Northern and Eastern provinces of Sri Lanka. It has been observed that the disease incidence is much higher in these non-traditional rubber growing areas where the environmental factors are different and consequently the natural vegetation is also dissimilar to the traditional rubber growing areas.

In this background, the objectives of the current study were to identify the local host species of the disease and to evaluate the potential role of those species in the development of brown root disease in rubber plantations when planted in non-traditional areas.

Methodology

Collection and maintenance of isolates

Seventy brown root disease incidences, which have been reported to the Department of Plant Pathology and Microbiology, Rubber Research Institute of Sri Lanka, for a period of three years (from 2014 to 2016) were used for the study. These incidences were from different agro-ecological regions of the country.

In order to identify the possible alternative host species of the brown root disease of rubber, the presence of infected non-rubber species in the vicinity of the infected rubber trees was investigated. In each of the incidence, the firstly-diseased rubber tree was traced and the root system of the tree was exposed in order to find out the association of the roots of the neighboring trees with the respective rubber tree. Diseased root samples were collected from the other host species which were having root contacts with the diseased rubber tree. The signs and the symptoms of the collar and the root systems of both the rubber tree as well as the associated tree were recorded.

Koch's postulates and cross infection studies

In order to confirm the pathogenicity of the isolated fungi, Koch's postulates was proven with each isolated fungus. For the artificial inoculation, an artificial medium was used. In the medium, 100g of rice bran and saw dust (1:2 w/w) was used as the substrate of the fungus. The prepared medium was autoclaved for 45 minutes at 121ºC in polypropylene bags and the fungal isolate grown on MEA was used on the inoculation. Two agar blocks of 30 cm^2 from the advancing margin of the above cultures were transferred aseptically into each bag of autoclaved medium and incubated for 12 weeks at RT (28±2ºC) under dark conditions. Four six-month old healthy seedlings of each species were grown in pots in a greenhouse and artificially inoculated using the inocula prepared as described above. After four months of inoculation, signs and symptoms of the seedlings of each species were recorded and the pathogens were re-isolated onto MEA from the roots of the artificially inoculated seedlings.

The seven different isolates were tested for the cross infection ability among the species from which they were isolated as well as with rubber. The same artificial inoculation technique which was used to prove the Koch's postulates was used for this study. All the seven isolates from alternative species were tested for the ability to infect four six-month old rubber seedlings and a *Phellinus noxius* isolate obtained from rubber (which was in the culture collection) was tested for the ability to infect four six-month old seedlings of the each respective species. After four months of inoculation, signs and symptoms of all seedlings were recorded and the fungus was re-isolated onto MEA from the roots of the artificially inoculated seedlings.

Cultural characteristics and the rate of growth

For the cultural characteristics and the rate of growth studies, a 9.0 mm mycelial plug taken from the advancing margin of a three-day old culture of the test isolate was placed at the center of Petri plate. The plates were incubated at room temperature under 12 hours light and dark regimes.

Growth of the isolates was evaluated on four media; Malt extract agar (MEA), Potato dextrose agar (PDA), Czapec-dox agar (CDA) and Lima bean agar (LBA) (Oxoid). The growth was determined after 04 days by measuring colony diameter along two perpendicular lines of each Petri plate. Five replicates were used in the experiment.

Cultural characteristics were evaluated on MEA (Oxoid). Coloration, fluffiness and the density of the cultures were recorded after four days of inoculation. Ranks from 0-5 were given for the brownish colouration developed in the culture, as the rank zero and five being the lowest and highest colourations of the cultures respectively. The fluffiness was ranked from 1-4 as the rank one and four being the lowest and highest fluffiness respectively. The density was ranked from 1-3 as the rank one and three being the lowest and highest densities of the cultures respectively. Five replicates were used in all experiments.

The fungal cultures were subjected to identification based on the cultural characteristics after four days of inoculation. Commonwealth Mycological Institute (CMI) description sheets were used as a guide to identify the isolated fungus.

Studies on the land history and associated species

In order to identify the mode of disease spread and the origin of the pathogen innoculum, the species history of the land was investigated in all seventy disease incidences. Moreover, information was gathered on the cut-trees having root contacts with the firstly-diseased rubber tree. A structured questionnaire was used to gather the information.

Results and Discussions

The host species reported

Decayed roots of twenty six species which were having root contacts with the diseased rubber trees were identified. The pathogen isolates could be obtained from seven alternative species (Table 1).

Table 1. P. noxius *isolates collected from species other than rubber*

Name of the isolate	Host species	Location	Agro-ecological zone
AH 1	*Cereya arborea* (‘kahata’)	Warakapola, Sri Lanka (7°08'22.8"N 80°14'04.2"E)	WL2b
AH 2	*Gmelina arborea* (‘eth demata’)	Badalkumbura, Sri Lanka (6°55’1.165"N 81°13'31.246"E)	IM2b
AH 3	*Bridelia retusa* (‘keta kela’)	Bulathkohupitiya, Sri Lanka (7°05' 27.838"N 80°20' 9.449"E)	WL1a
AH 4	*Mangifera indica* (mango)	Moneragala, Sri Lanka (6°53' 30.663 "N 81°18' 31.948"E)	IL1c
AH 5	*Artocarpus heterophyllus* (jack)	Gampaha, Sri Lanka (7°06 2.652 "N 79°59'42.359"E)	WL3
AH 6	*Tectona grandis* (Teak)	Hopton, Sri Lanka (6°59' 31.56"N 81°11'55.68"E)	IL1c
AH 7	*Cinnamomum zeylanicum* (Cinnamon)	Polgahawela, Sri Lanka (7°20’ 26.967”N 80°16’ 41.978”E)	IL1a

In addition to the above hosts, nineteen species were reported to be present in association with the firstly-diseased rubber tree (Table 2). The decayed root pieces were present *in situ* having root contacts with the diseased rubber tree(s). However, the pathogen isolates could not be obtained from them, as the root segments were too decayed.

Symptomatology of the disease on rubber and alternative hosts

Slow plant growth, yellowing and wilting of leaves, defoliation and branch dieback were the major above-ground symptoms (Figs. 1a & 1b). Roots of rubber infected with *P. noxius* initially exhibited a brown discoloration of the wood just beneath the bark (Figs. 1c). On the roots, tawny brown gummy mycelia were observed firmly fixed to the outer bark surface with an encrustation of sand and stones on the root surface. They were identified as the characteristic diagnostic symptom of *P. noxius* on rubber (Fig. 1d). The dead wood becomes white, dry, and honey-combed (Fig. 1e). Bracket-like hard fructifications are rarely observed on the basal trunk of diseased trees. The fructification are dark brown on the upper surface and dark grey on the lower surface (Fig. 1f & 1g).

Table 2. *Forest tree species observed in association with the firstly-diseased rubber tree*

Serial no	Host species	Vernacular name
1	*Elaeocarpus* spp.	Weralu
2	*Artocarpus nobilis*	Wal del
3	*Michelia champaka*	Ginisapu
4	*Swietenia mahagoni*	Mahogani
5	*Stereospermum personatum*	Lunumidella
6	*Stereospermum chelonoides*	Palol
7	*Adina cordifolia*	Kolon
8	*Vitex pinnata*	Milla
9	*Chloroxylon swietenia*	Burutha
10	*Schleichera oleosa*	Kon
11	*Gliricidia sepium*	Gliricidia
12	*Ficus religiosa*	Bo
13	*Albizia odoratissima*	Sooriya Maara
14	*Syzygium assimile*	Domba
15	*Semecarpus coriaceae*	Badulla
16	*Hybanthus enneaspermus*	Makulla
17	*Schleichera oleosa*	Khone
18	*Macaranga peltata*	Kenda

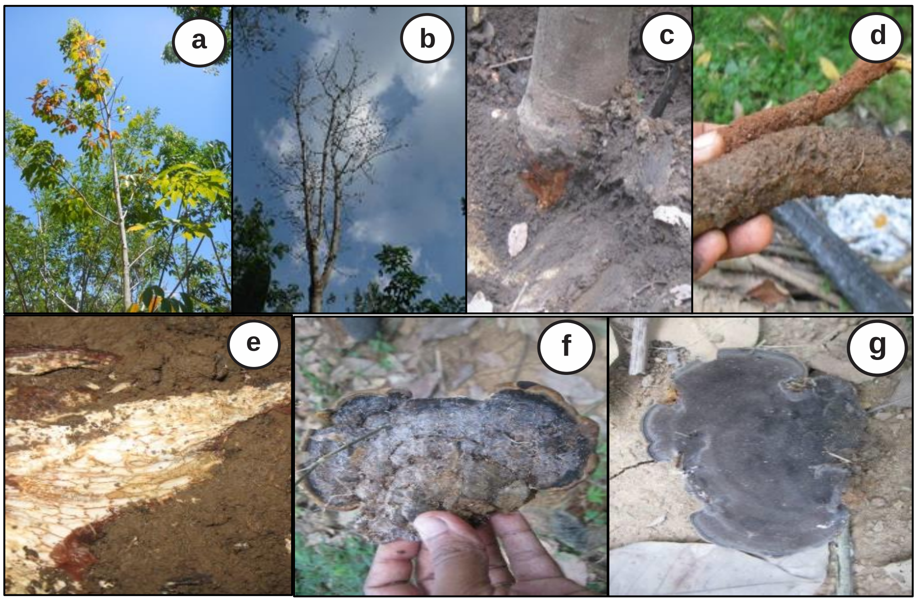

Fig. 1. Signs and symptoms of the brown root disease on rubber

As the disease incidences were reported at the latter stages of the infection of the rubber trees, all the associated species were diagnosed to have infected after the death. Therefore, no foliar symptom could be identified from those species. However, encrustation of sand and stones on the root surface could be observed due to the gummy rhizomorphs firmly fixed to the outer bark surface (Fig. 2a). The dead wood had become dry and honey-combed (Fig. 2b). Infected roots had exhibited a brown discoloration of the wood just beneath the bark (Fig. 2c). The inner bark was covered with the white to brownish mycelial mat (Fig. 2d). Fructifications were observed on the basal trunk of only two species *Cereya arborea* and *Stereospermum personatum* (Fig. 2e).

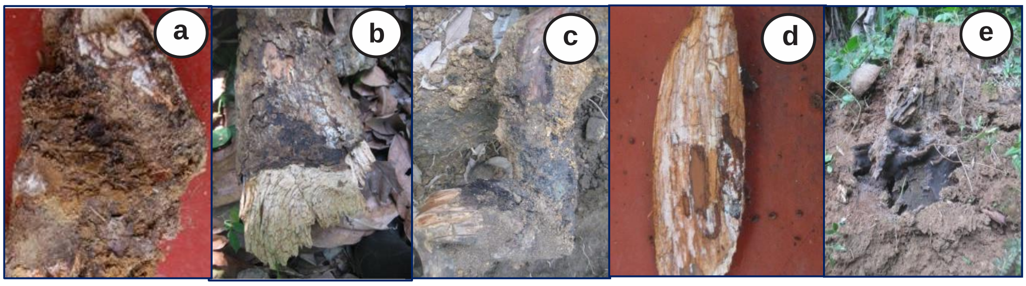

Fig. 2. Signs and symptoms of the brown root disease on non-rubber species

Koch's postulates and cross infection studies

Signs and symptoms of the plants of the seven species resulted after the Koch's postulates were similar to those observed under the natural conditions. As the above-ground symptoms, the turning of the leaves to yellowish brown color and in advanced stages, shedding of the leaves and die-back of the affected branches. The roots were covered with tawny brown gummy rhizomorphs and the encrustation of sand and stones on the root surface was also observed. The cultural characteristics of the re-isolated fungus was similar to those of the original isolate. Moreover, the seven different isolates showed cross infection ability among the species from which they were isolated as well as with rubber.

Growth rate of the isolates

The growth of seven different isolates showed variability on different culture media. Based on the growth rate, MEA was selected for the colony morphology studies. Isolates AH1 and AH2 showed a fastest growth on all media tested (2.14 cm/day and 2.13 cm/day respectively on MEA) while the isolate AH4 showed the slowest growth rate (1.8 cm/day) on MEA (Fig. 3).

Morphological variation of the isolates

Colonies grown in the laboratory showed distinctive raised brown and white plaques (patches) characteristic to *Phellinus noxius* and produced arthrospores, which are asexual spores formed by the division of special hyphal segments. The fungus was identified as *Phellinus noxius*: the causative fungus of the brown root disease of *Hevea brasiliensis* with the guidelines of the Commonwealth Mycological Institute (Pegler and Waterston, 1968).

The different isolates of *Phellinus noxius* showed variations in colony morphology (Fig. 4).

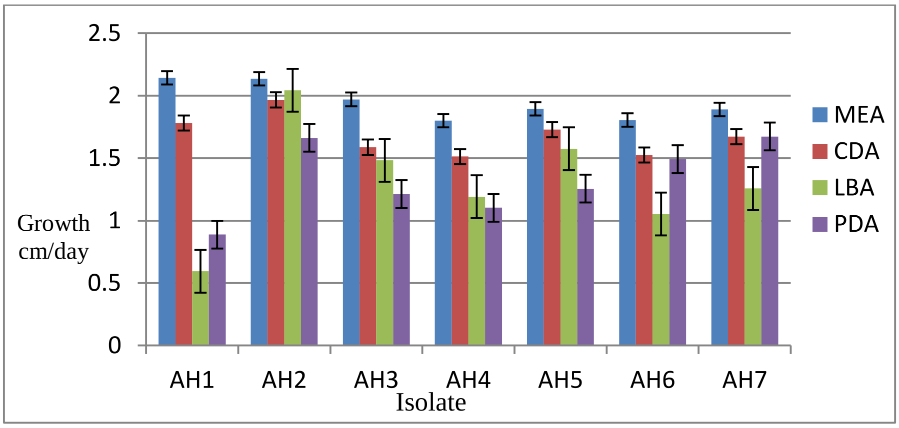

Fig. 3. Growth rates of the seven *Phellinus noxius* isolates on different culture media MEA, CDA, LBA and PDA (Error bar represents the variation around the mean values)

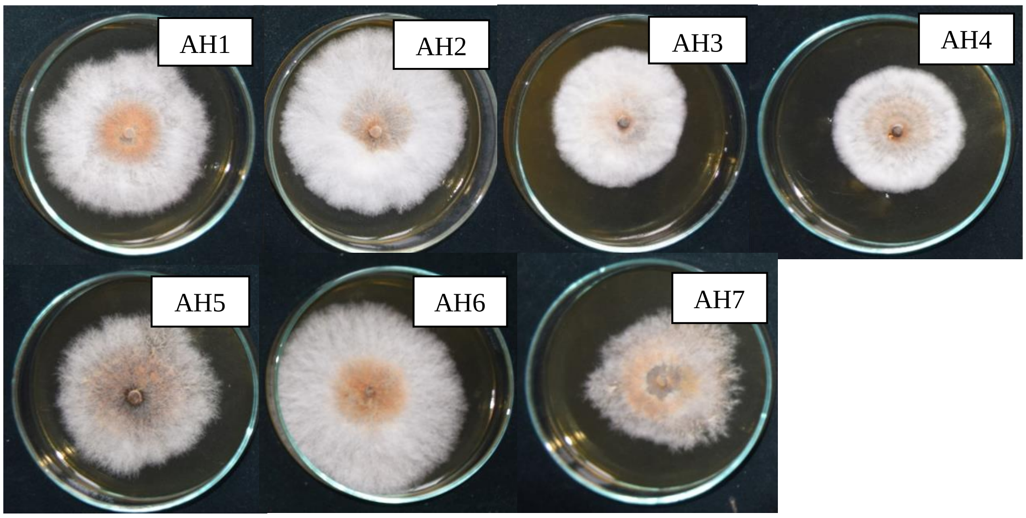

Fig. 4. Variability in cultural morphology *Phellinus noxius* - 03-day old cultures

Land and root zone studies

Seventy brown root disease records on rubber were received from various parts of Sri Lanka during the study period. According to the information, it was observed that the initially diseased rubber tree had a root contact with a diseased root of some other species in all seventy disease incidences. When the host species profile is considered, except for a few cultivated species such as cinnamon, mango and teak, almost all the other species were of forest-origin. Moreover, it could be observed that even these three species were not intentionally-planted in these lands and had a wild origin. When the species history of these lands was considered, it was noticed that 11 (84.28% of the total) of the reported incidences being rubber established after clearing native forests. The rest of the lands has been abandoned for years with trees and shrubs of forest origin or having an neighboring forest land by which the rubber trees can get root contacts.

When E. J. Corner described *Fomes noxius* (currently *Phellinus noxius*) as a new species in 1932, he mentioned that it was usually found in cleared or disturbed areas. Since the beginning of the 20th century, many plantations of rubber, tea, cocoa, coffee, oil palm, and mahogany established on cleared forest sites had been damaged or destroyed by *P. noxius* (Pegler *et al.*, 1968). According to these facts, it can be expected that the innoculum is present in native tropical forests of Sri Lanka. New infection centers may have been initiated when roots of the newly planted trees make contact with infected stumps or other woody debris of cleared native forest.

When the features of land preparation is concerned, it could be observed that all these rubber cultivations had been established after a minimum land preparation and consequently, roots of forest species have not been uprooted (Fig. 5).

Fig. 5. Infected roots and stumps of forest species in rubber clearings: note the disease signs and symptoms on roots of non-rubber species

Furthermore, in 67 incidences (95.71% of the total), the disease was from the smallholder rubber fields, where rubber is planted after a minimum land preparation or rubber is planted in mixed cropping systems with some other crop or garden species.

According to the past records in Sri Lanka, brown root disease causing fungus was of very common occurrence in the earlier days of rubber planting in Ceylon, when rubber was inter planted in cocoa and tea fields. The dead stumps remained after the removal of cocoa and tea by cutting off the bushes and leaving the stumps, the rubber trees later get infection (Advisory Circular of RRISL, 1954). The initial infection occurs when roots of the newly planted trees make contact with stumps or other woody debris that contain the fungus (source of inoculum). Further spread from the initial infection centers is through root contact. *P. noxius* can persist in the roots and stumps of infected plants for more than ten years after the death of the host (Chang, 1996).

Conclusion

Based on these facts, it could be concluded that the infection of brown root disease to rubber in the studied locations in Sri Lanka was found to be due to root contact with diseased other tree species. Moreover, it was found that the innoculum was present in native forests on infected roots or woody debris. The results of this investigation indicated a variation in morphological and physiological characters and symptoms amongst the population of *Phellinus noxius* isolates from non-rubber species in Sri Lanka.

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The effect of the container and the potting media of nursery plants on the growth of rubber plants: experience with root trainers to raise rubber plants

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Abstract

Young buddings raised in 15 cm x 37 cm, gauge 300 black polythene bags filled with top soil are the recommended planting materials for rubber planting in Sri Lanka. The proprietary plastic root trainers are recommended in India along with a unique and rich potting mixture which is not available or affordable under local conditions. Proprietary root trainers 30 cm x 9 cm (diameter at the top and 1000 cc, and 15 cm x 37 cm recommended young budding bags with a hole at the base of the bag were tested along with two cone shaped polythene containers, having 32 cm x 9 cm (diameter at the top) and 1160 cc, 40 cm x 15 cm (diameter at the top) and 2000 cc. Six different combinations of coir pith, sand, top soil, saw dust and compost were tested with 100% top soil and 100% coir pith as the potting media.

The results indicated that the volume, the shape of the container or the potting medium have minimum impact on the survival percentage of the seedlings or on the quality of the budded plants. Nevertheless, 100% coir pith seems to affect the survival rate of seedlings. The growth measured up to two years in the field confirmed no difference among the container or the potting medium.

Key words: *Hevea*, polybag, root growth, root trainer, rubber, young budding

Introduction

In Sri Lanka the extent under rubber cultivation is 130,319 ha. as per the latest statistics available (Anon, 2017). In order to maintain this extent, 3.3% of this extent should be replanted annually. New planting takes place in non-traditional rubber growing areas, under various projects but only to a limited extent. Annual planting material requirement in Sri Lanka is 2.5-3 million plants and since 2003 the type of planting material used is young buddings as recommended by the Rubber Research Institute of Sri Lanka. Research has been carried out by many scientists and the current recommendation is based on trials conducted at the Rubber Research Institute of Sri Lanka for many years from 2002 (Seneviratne, 2002, 2003, 2004, 2005) and (Seneviratne *et al.,* 1994).

Polybags of 6” x 15” size (15 cm x 37 cm) made out of gauge 300, black polythene are recommended to raise young buddings in traditionally rubber grown districts. For non- traditional areas of Sri Lanka such as Moneragala and Ampara, the recommended bag size is 7” x 18” (17 cm x 42 cm) as the nursery period is longer and climatic conditions are not conducive for plant growth. Root coiling at the base of the polybag is considered as a shortcoming in young buddings and this has not been studied in depth. But the tap root of the seedlings penetrates the base of the bag after coiling. However, a hole made at the center of the base of the bag seems sufficient to allow the tap root growth without coiling (Anon, 2009). However, when the size of the bag is smaller than the currently recommended size, the tap root tends to penetrate the bag without coiling since the area at the base is smaller. Since the large scale young budding plant production was initiated in government rubber nurseries under the management of RRISL in 2002-2003 period, manual polybag preparation using polythene tubing was stopped and polythene suppliers were requested to supply perforated and guzzetted bags of desired gauge and size.

Plastic cone shaped containers known as root trainers were developed in India in 1999 (Soman and Saraswathyamma, 1999), initially to grow bare root budded plants up to 2-3 whorl stage. The potting mixture recommended for root trainers was sieved coir pith and cow dung in 1:1 ratio, neem cake 500g, phosphate 10g, Mancozeb 75WP (10g) and super phosphate 250 g per $0.028m^3$of potting medium**.** But to compare the growth, conventional polybags had been filled with just top soil. Germinated seeds have also been tested with root trainers by Soman and Saraswathyamma (1999) and found to be satisfactory to grow seedlings up to 2-3 leaf whorl stage, to be bud grafted and allowed the scion to attain the desired growth.

Coir pith is free and found in abundance in India, but in Sri Lanka it is widely used for value addition and therefore not free. The planting material requirement in India is about six times of that of Sri Lanka and part of the planting material requirement is supplied as root trainer plants by private nurseries. They do not discuss about the quality of plants but mainly focus on ergonomics. However, the capital investment is high to produce plants using root trainers. The necessary infrastructure changes in the nurseries are costly which should be recovered through adding the cost to the plants. Nanhorya *et al.*, (1999) also, while accepting root trainers, state the need of heavy capital investment to raise root trainer nurseries. Further, they accept the fact that India cannot afford such capital investment and recommend what is called a polytube to raise young buddings. Some estates under Regional Plantation Companies in Sri Lanka too started root trainer technique but stopped after 2-3 seasons due to failures in plant production using this technique. In this context, there was an interest and requests from the nursery owners to test and report on the performance of the proprietary root trainers. The objective of this study therefore was to find the best container and potting medium for raising young buddings and especially to see the growth performance of young buddings in root trainers.

Materials and Methods

This experiment was conducted at the main research station of the Rubber Research Institute of Sri Lanka (RRISL) at Dartonfield, Agalawatta. Fresh rubber seeds were collected and were sown in germination beds and the early germinated seeds were harvested and planted in polythene containers and proprietary root trainers. Maintenance of the plants and the manuring were done as per the RRISL recommendations given in Advisory Circular 2016/04-Fertilizer to Rubber and Advisory Circular 2016/09-Production of Budded Plants.

Root trainers were supplied for this study by a prospective supplier of root trainers in Sri Lanka. Recommended size (15 cm x 37 cm) polybags were used as the control treatment. Two other large size cone shaped containers made manually out of gauge 500 black polythene were also tested. Details of the containers used in the study are given in Table 1.

Potting mixtures

Composition of eight different potting media, tested with different containers are given in Table 2. Coir pith was bought from a regular supplier in the area. River sand was also from a regular supplier and top soil was dug from an abandoned area of the Dartonfield estate. Mixing was done manually as per the compositions given.

Table 1. *Dimensions, materials and volumes of the containers tested to raise young buddings*

Type	Size Diameter at the top x Height (cm)	Material	Volume (cc)
1	Cone shaped containers of 9 x 32	Black polythene cone	1,160
2	Cone shaped containers of 15 x 40	Black polythene cone	2,000
3	Root trainers of 9 x 30 (proprietary root trainer)	Black plastic root trainer	1,000
4	Normal YB bags of 15 x 37 with a central hole at the base	Black polythene	2,350

Table 2. *Composition of potting media used for filling bags and root trainers*

Type	Composition	Ratio v/v
A	Coir pith sand	1:1
B	Coir pith + sand + top soil	1:1:1
C	Saw dust + sand	1:1
D	Saw dust + sand + top soil	1:1:1
E	Sand + top soil	1:1
F	Compost + sand + top soil	1:2:1
G	Top soil	100%
H	Coir pith	100%

Design and data collection

There were 24 replicate plants for each polythene container whilst only six replicates for the root trainer due to limited number supplied. Media filled containers were arranged as RCBD.

Survival of seedlings was counted after three and seven months and percentages were calculated. Height and girth measurements were also recorded.

Seedlings were bud grafted with green budwood of clone PB 260. Height and diameter the scion shoot were collected after seven months of bud grafting. All plants were field planted.

Results

The survival percentage of seedlings in four different containers and in eight different media after 3 months are given in Table 3.

As it can be seen from Table 3, survival percentage after 3 months is about 88% in all container types and different media. But, the number survived reduced afterwards and, the number of seedling plants survived after seven months in four containers and eight potting media are given in Table 4.

Table 3. *Survival percentage of seedlings in four containers and in eight potting media after three months of transplanting*

Container type	**Potting medium**							
Diameter at the top x Height (cm)	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Cone shaped containers of 9 x 32	96	100	96	100	96	100	96	96
Cone shaped containers of 15 x 40	100	100	88	96	100	100	100	96
Root trainers of 9 x 30 (proprietary root trainer)	100	100	100	100	100	100	100	86
Normal YB bags of 15 x 37 with a central hole at the base	100	100	86	100	100	100	100	100

Table 4. *Survival percentage of seedling plants in four container types and eight potting media after 7 months*

Potting medium								
Container type Diameter x Height at top (cm)	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Cone shaped containers of 9 x 32	20.8	29.2	37.5	45.8	25	12.5	25	0
Cone shaped containers of 15 x 40	37.5	29.2	33.3	45.8	12.5	33.3	33.3	20.8
Root trainers of 9 x 30 (proprietary root trainer)	33.3	0	33.3	100	33.3	33.3	33.3	50
Normal YB bags of 15 x 37 with a central hole at the base	29.2	29.2	20.8	29.2	75	37.5	45.8	0

As it can be seen from Table 4, survival percentage has reduced at bud grafting. However, 100% survival rate is seen with root trainers filled with saw dust, sand and top soil (1:1:1: medium, D). The lowest survival rate is seen with 100% coir pith in small cone shaped container and normal polybag with a central hole at the base.

Mean height of the scion shoots after seven months are given in Table 5. SEM values are given in brackets.

Table 5. *Mean height of the shoots (cm) in four container types and eight potting media after 7 months. SEM values are given in brackets*

Container type Diameter at the top x Height (cm)	**Potting mixture** A	B	C	D	E	F	G	H	**Mean**
Cone shaped containers of 9 x 32	57 (±10)	96.4 (±12)	85.2 (±5)	74.6 (±6)	62.8 (±9)	62.3 (±5)	77.7 (±10)	-	73.7
Cone shaped containers of 15 x 40	74.2 (±7)	88.3 (±6)	91.4 (±8)	114.9 (±9)	59.3 (±7)	113 (±7)	76.2 (±7)	70.6 (±10)	86.0
Root trainers of 9 x 30 (proprietary root trainer)	102.5 (±17)	-	102.5 (±17.5)	93.3 (±13)	83 (±7)	84 (±1)	81.5 (±12)	55.7 (±11)	86.0
Normal YB bags of 15 x 37 with a central hole at the base	77.8 (±11)	91 (±12)	82.6 (±11)	78.1 (±9)	78.3 (±5)	65.7 (±5)	69.1 (±5)	-	77.5
Mean	77.8	91.9	90.4	90.2	70.8	81.2	76.1	63.1	

The lowest mean height (55.7 cm) is given by plants grown in root trainers in 100% coir pith. However, the highest mean height 114 cm is seen in plants grown in saw dust, sand and top soil medium in 15 cm x 40 cm black polythene cone shaped containers. But high variation among seedling height is seen in all container types and in all media.

Mean diameter of shoots after 7 months in four container types and eight potting media are given in Table 6.

Table 6. *Mean diameter (cm) of shoots after 7 months in four container types and eight potting media. SEM values are given in brackets*

Container type Diameter at the top x Height (cm)	**Potting mixture** A	B	C	D	E	F	G	H	**Mean**
Cone shaped containers of 9 x 32	0.98 (±0.11)	1.28 (±0.12)	1.33 (±0.08)	0.995 (±0.06)	1 (±0.12)	0.783 (±0.06)	1.1 (±0.11)	-	1.1
Cone shaped containers of 15 x 40 (diameter at the top and height respectively)	1.24 (±0.11)	1.52 (±0.11)	1.325 (±0.14)	1.41 (±0.09)	1.3 (±0.06)	1.45 (±0.1)	1.31 (±0.12)	1.15 (±0.15)	1.3
Root trainers of 9 x 30 (proprietary root trainer)	1.55 (±0.25)	-	1.15 (±1.5)	1.14 (±0.07)	1.35 (±0.05)	1.2 (±0.2)	1.3 (±0)	0.93 (±0.09)	1.2
Normal YB bags of 15 x 37 with a central hole at the base	1.17 (±0.07)	1.37 (±0.11)	1.17 (±0.162)	1.31 (±0.103)	1.11 (±0.05)	1.16 (±0.107)	1.18 (±0.052)	-	1.2
Mean	1.2	1.39	1.2	1.2	1.2	1.1	1.2	1	

Mean diameter of plants vary from 0.78 to 1.4 cm but the mean values for the different containers only vary from 1.1 cm to 1.3 cm.

The diameter of the plants raised in the cone shaped black polythene containers which holds 2000 cc capacity show the best performance. This container has a hole at the bottom as in the proprietary root trainer but holds twice the volume of potting medium than in the root trainer.

The currently recommended polythene bag holds the highest volume of potting medium but it is observed that in most cases the tap root coils at the base before penetrating to the ground.

Mean girth of the plants measured at 10 cm above the ground level after one year of field planting are given in Table 7.

It can be seen from the data in Table 7 that the mean girth of the trees grown in different media and in different containers vary from 4.95 cm to 9 cm, one year after field planting.

Mean girth of plants measured at 10 cm above the ground level after two years of field planting are given in Table 8.

Table 7. *Mean girth of the plants (cm) measured at 10 cm above the ground level after one year of field planting are given in Table 8. SEM values are given in brackets*

Container type	Potting Medium								Mean
	A	B	C	D	E	F	G	H	
Cone shaped containers of 9 x 32 (diameter at the top and height respectively)	7.9 (±0.58)	6.95 (±0.66)	7.55 (±0.79)	7.61 (±0.35)	7.14 (±0.42)	7 (±0.41)	7.94 (±0.59)	-	7.4
Cone shaped containers of 15 x 40 (diameter at the top and height respectively)	8.05 (±0.6)	8.6 (±0.66)	7.92 (±0.71)	8.75 (±0.43)	6.5 (±0.29)	7.83 (±0.59)	8 (±0.73)	9 (±0.73)	8.1
Root trainers of 9 x 30 diameter at the top and height respectively (proprietary root trainer)	6.85 (±0.65)	-	6.75 (±1.25)	7.75 (±0.25)	-	7.25 (±0.75)	-	7.67 (±1.45)	7.3
Normal YB bags of 15 x 37 with a central hole at the base	7.86 (±0.67)	8.14 (±0.58)	7.5 (±1.5)	7.05 (±0.91)	7.93 (±0.36)	8 (±0.57)	6.8 (±0.35)	4.95 (±0.45)	7.3
Mean	7.7	7.9	7.4	7.8	7.2	7.5	7.6	7.2	

The girth measurements of field planted plants were measured after two years of field planting. The girth values vary from 13.4 cm to 13.7 cm indicating minimum effect of the container.

The mean girth of the plants grown in different potting media at field planting, one year after field planting and two years after field planting are given in Table 9 and Figure 1.

Table 8. *Mean girth (cm) measured at 10cm above the ground level after two years of field planting. SEM values are given in brackets*

Container type diameter at the top and height (cm)	**Potting medium**								**Mean**
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**	
Cone shaped containers of 9 x 32	13.5 (±1.1)	10.4 (±1.02)	13.35 (±1.07)	13.7 (±0.76)	13.3 (±0.86)	13.3 (±2.4)	15.9 (±0.29)	-	13.4
Cone shaped containers of 15 x 40	14.1 (±0.71)	13.6 (±0.88)	12.3 (±0.93)	16.04 (±0.51)	12.1 (±0.31)	13.4 (±0.97)	13.6 (±1.28)	14.5 (±1.55)	13.7
Root trainers of 9 x 30 (proprietary root trainer)	12.5 (±1.5)	-	13.5 (±1.5)	14.2 (±0.81)	-	14.05 (±1.25)	-	14.3 (±2.33)	13.7
Normal YB bags of 15 x 37 with a central hole at the	13.8 (±0.8)	14 (±0.89)	14 (±0.5)	13.8 (±0.92)	13.7 (±0.68)	13 (±0.8)	12 (±0.38)	-	13.5
Mean	13.5	12.7	13.3	14.4	13	13.4	13.8	14.4	

Table 9. *Mean girth (cm) of field planted plants grown in different potting media at field planting, one year after field planting and two years after field planting*

Parameter	A	B	C	D	E	F	G	H
Girth at Planting	3.8	4.4	3.8	3.8	3.8	3.5	3.8	3.1
Girth at 1 year	7.7	7.9	7.4	7.8	7.2	7.5	7.6	7.2
Girth at 2 year	13.5	12.7	13.3	14.4	13	13.4	13.8	14.4

The mean girth of the plants grown in different containers at field planting, one and two years after field planting are given in Table 10 and Figure 2.

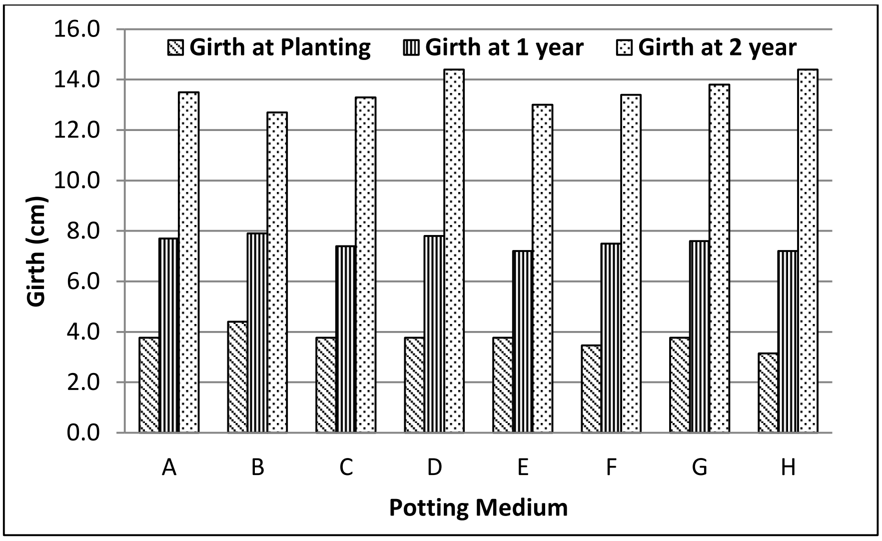

Fig. 1. Mean girth (cm) of field planted plants grown in different potting media at different at field planting, one year after field planting and two years after field planting

Table 10. *Mean girth (cm) of field planted plants with different container type at field planting, one and two years after field planting*

Parameter	Cone shaped containers of 9 cm x 32 cm (diameter at the top and height respectively)	Cone shaped containers of 15cm x 40 cm (diameter at the top and height respectively)	Root trainers of 9cm x 30cm diameter at the top and height respectively (proprietary root trainer)	Normal YB bags of 15 cm x 37 cm with a central hole at the base
Girth at Planting	3.5	4.1	3.8	3.8
Girth after 1 year	7.4	8.1	7.3	7.3
Girth after 2 years	13.4	13.7	13.7	13.5

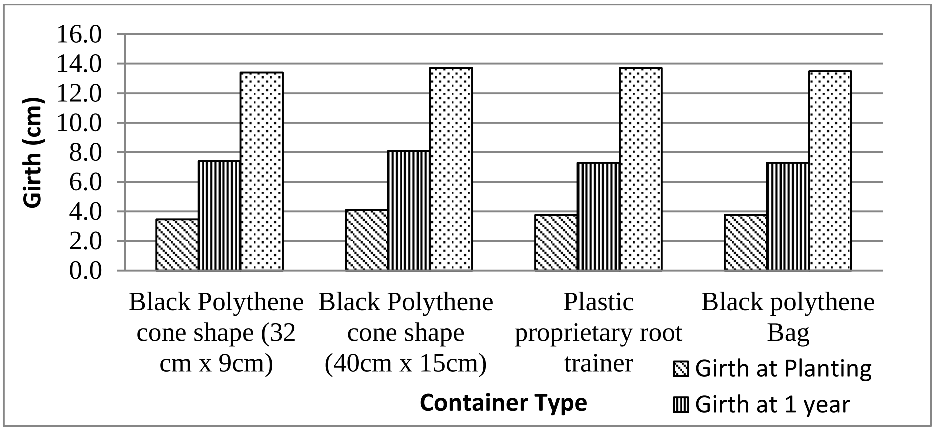

Fig. 2. Mean girth (cm) of field planted plants with different container type at field planting, one year after field planting and two years after field planting

Discussion

In the present study, the main difference among containers was the volume of the container. The similarity was the presence of a hole at the base of the container including poly bags. Root trainers and other two containers were cone shaped and young budding polybag was cylindrical.

The effect of the container on the growth of the seedling plants should be seen only during the initial period as the taproot penetrates the base of the bag within the first 4-5 weeks of transplanting of the geminated seeds into bags. Accordingly, after one month of transplanting, the tap root penetrates the bag and grows underground. Coiling of the tap root at the base of the bag is a common issue with poly bag plants, when polybag has no central hole at the base.

Coiling of the taproot at the base of the bag has been checked against the bags with central holes (Annual Review, 2011). When a central hole is introduced at the base of the bag, irrespective of the size of the hole (either ½" or ¾ square shape hole) root coiling has not been seen in about 50% of the plants. The normal 15cm x 33cm perforated bag has resulted about 50% of fully coiling at the base and another 16% half coiled, as reported by Seneviratne (2011).

In the present study root coiling was not monitored but growth of the seedlings and the grafted plants were measured. As reported by Seneviratne *et al.* (1994), the growth of the young buddings is affected by the size of the container. The currently used bag size was recommended in order to achieve buddable girth in 3-4 months. In the present study, the height of seedlings shows a large variation form 55 cm to 114 cm. This is mainly due to time taken by individual seedlings to develop a new flush. In seedlings inter-nodal length is about 25 cm. The effect of the medium should be minimum due to tap root penetrating to the ground during one month or so, however, as shown by data, mean girth is almost the same among the container types also, as the tap root penetrated to ground and grown outside the container. Diameter is the only growth parameter important in the process of plant production as bud grafting can be done when the diameter of the seedling is more than 6mm. Without a proper root system, growth of the areal part of the plant will not happen. The lateral root growth within the bag depends on the medium; compost and coir pith improves lateral roots inside the container (Plate 1) but it is a waste of resources as the lateral roots die when the stock plant is cut back after bud grafting and regenerate with the growth of the grafted bud (Dharmakeerthi, *et al.*, 2008).

Wilson 1986 has mentioned that severing the tap root at the point of coiling may result in the loss of nearly one third of the root system and give a severe shock to the plant leading to heavy casualty on transplanting. This is practiced in Sri Lanka successfully by tailing the tap root about 10 days before transporting to the field. The size of the root trainer recommended by Soman and Saraswathyamma (2005) is 7.5 cm diameter at the top and 30 cm length. The poly bag tested by them was 55 x 25 cm. Accordingly, a longer tap root (25 cm more) is accommodated even if the tap root is cut at the base when coiling started. As both the root trainers and polybags had been arranged in trenches of 30 cm deep, until they grow up to 2 leaf whorl stage (4-5 months) and the root system had grown out. More over method of manuring had been different as root trainer plants were drenched with 2% solution of N:P:K:Mg 10:10:4:105 at weekly intervals while polybag plants had been manured monthly with the same solid mixture of the 10-30g during the 4 months period. In addition, a proprietary mixture of micronutrient solution had been sprayed on root trainer plants at fortnightly intervals. Once the plants attend 2 whorl stage, then the root trainers were lifted and kept on carriers made out of bamboo splinters after pruning the roots that had grown out of the root trainer. As reported by them, (Soman & Saraswathyamma, 2005) both the diameter and the height of plants grown in root trainers are lower than those of polybag plants, which has been attributed to the low quantity of potting medium despite tap root grow outside the container. Number of lateral root had been higher in root trainer plants. This is mostly due to the rich medium and the personal experience on lateral root development in coir pith and compost mixed media is similar or even better in polybags (Plate 1). However, higher number of casualties has been recorded for polybag plants.

Plate 1. Rich lateral root development in coir pith and compost mixed media in polybags

Coir pith had been soaked in water for two weeks in order to remove tanning and other growth inhibitors and then dried prior to use. This would be a real practical problem when producing millions of plants. Further, when coir pith was used at 100%, all plants died at five weeks in small cone shape containers and normal polybags, possibly due to being toxic to roots as Soman & Sarawathyamma (2005) reported. They further stated that the tap root coils after 6-7 weeks of planting of bare root budded plants in polybags. The length of the polybags used by them is 55 cm while the height of a root trainer is only 30 cm. Therefore, even if the tap root is pruned at the coiling point, 55 cm long tap root is available at field planting when plants are grown in poly bags whereas only 30 cm long tap root is available with root trainer plants.

As reported by Dharmakeerthi *et al.* (2008) the root system inside the polybag get decreased up to 60% after cut back of the shoot after bud grafting.

Hardening is recommended in Sri Lanka also for young budding plants, by bending the bag and trimming the tap root with a pair of secateurs 10-15 days prior to field planting. Soman and Saraswathyamma (2005) recommend to lift root trainers to get the tap root pruned. After that root trainers are arranged off ground, in carriers made out of bamboo splints until field planting. However, the time and the cost incurred in these practices are real issues in large scale plant production.

Soman and Saraswathyamma (2005) have reported, mean girth of the plants grown in root trainers and poly bags up to four years in the field. At planting mean girth of 3.2 ±0.66 and 3.41±0.71 has been reported for root trainer plants and polybag plants. Similarly after one year in the field 6.43±0.89 and 6.11±1.12 have been reported for plants grown in root trainers and polybags, respectively. After four years in the field, 38.75±2.05 and 35.25±2.64 have been reported for root trainers and polybags, respectively. As it is clear from girth measurements, the effect of the container is not seen until the plants are transferred to the field. Similar observations have been reported in an experiment with different sizes of polybags.

Soman *et al*. (2002) claim that the cost of transportation, distribution and out planting as the most attractive aspects of root trainers.

Soman *et al.* (2011) have reported of using smaller root trainers of only 22 cm height with a holding capacity of 350 cc for direct seed planting followed by green budding. They have used 30 cm long 800 cc root trainers for bare root planting. A medium different from that of Soman (1999) has been used which contains coir pith mixed with powdered rock phosphate (5g), neem cake (5g), bone meal (5g) Pesticide (Phorate 10g @ 100mg) and fungicide (Dithane M45 @ 100mg) to fill root trainers. Two polybag sizes 17.5 x 35.5cm and 25 x 55 cm have been used for direct seed planting and bare root planting, respectively filled with top soil mixed with rock phosphate. No significant differences have been reported among root trainers or polybags of two sizes each for budding success, scion establishment, height of the scion or more importantly diameter of the scion.

Soman *et al.* (2014) reported of an alternative potting medium for root trainer, a mixture of top soil, compost and cow dung with other ingredients. They have reported of no significant effect of the medium on various growth parameters like height, diameter, number of leaf whorls, total number of leaves *etc.* but on the number of lateral roots produced per seedling. They concluded the trial recommending many compositions for the potting medium.

Sumesh *et al.* (2015) reported that root restriction and air pruning of roots in root trainer plants has a significant effect on adaptation of the plants to survive better under harsh environments. The same technique is followed in normal young budding techniques in Sri Lanka by growing them in small size bags and tailing the tap root 2 weeks prior to planting.

However, the nursery period to rubber plants is about 10 months. In Sri Lanka, we are compelled to start the root stock nursery with the seed fall in August and the planting season is May/June with the on-set of the Southwest monsoon rain. The ideal method to raise rubber plants in Sri Lanka is the young budding technique which guarantees the high quality through selecting vigorous rootstocks and quality controlling of budwood. The plant should start growing in the field with proper establishment of its root system.

The biggest concern with root trainers is the nursery arrangement which is not only costly but also cumbersome. When the plants are transported, the vehicles should be specially prepared for that with metal frames fixed to keep plants erect.

In conclusion, the quality of rubber plants depends on the quality of seeds and the quality of budwood. The container and the potting medium have minimum effect on the ultimate quality of the plant but growth at a given time. Root coiling at the base of the normal poly bag could be stopped with a central hole, prepared at the center of the base of the bag. Also, this study shows that size of the bag can be further reduced which will be an added advantage. Moreover, the currently recommended 15 cm x 37 cm polybag with a central hole at the base filled with a mixture of top soil and coir pith can be used to young buddings successfully while depending on the availability of the other types different media can be used but not 100% coir pith.

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