International Symposium on Sustainable Plantation Management (ISSPM)-2023

Proceedings

Organized by
National Institute of Plantation Management
Ministry of Plantation Industries
Sri Lanka

04th August, 2023
Hotel Queensbury, Malabe
Sri Lanka

National Institute of Plantation Management

ISSN 2613-8387

ISBN 978-624-5660-02-5

Published by

National Institute of Plantation Management
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Sri Lanka

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MESSAGE OF THE SYMPOSIUM ORGANIZING COMMITTEE

It is our utmost pleasure to welcome you to this prestigious event organized by the National Institute of Plantation Management (NIPM), Sri Lanka. The International Symposium on Sustainable Plantation Management 2023 (ISSPM 2023) serves as a crucial platform for scholars, researchers, industry professionals, policymakers, and other stakeholders to come together and exchange knowledge, experiences, and insights on sustainable practices in plantation management global scale.

At NIPM, we are deeply committed to advancing the principles of sustainability in the plantation industry. We believe that sustainable plantation management is not just a responsibility but a necessity to ensure the long-term viability of plantations, conserve natural resources, protect biodiversity, and foster inclusive development for local communities across the world.

The theme of ISSPM 2023, "Sustainable Plantation Management" encapsulates our shared vision of creating a sustainable and resilient future for the plantations. It reflects our dedication to finding innovative solutions, promoting best practices, and addressing the challenges faced by plantations economy of respective countries.

ISSPM 2023 serves as a platform to foster collaboration, exchange knowledge, and showcase innovative approaches to sustainable plantation management. It provides an opportunity for us to learn from each other's experiences, gain insights from the latest research, and identify effective strategies that can be implemented on a global scale. Together, we can shape the future of plantation management to ensure the well-being of our planet and future generations.

We encourage all participants to actively contribute to the symposium by presenting your research findings, sharing success stories, and engaging in meaningful dialogues. ISSPM 2023 is an opportunity to showcase your work, inspire others with your insights, and contribute to the development of innovative and sustainable solutions for the challenges facing the plantation sector.

We would like to extend our sincere appreciation to all the participants, sponsors, and supporters who have made this symposium possible. Your commitment to sustainability and your invaluable contributions are instrumental in driving positive change and shaping the future of plantation management.

We are confident that this symposium will serve as a catalyst for collaboration, innovation, and transformative action in sustainable plantation management. Let us seize this opportunity to collectively work towards a better future, where our plantations thrive in harmony with the environment and serve as catalysts for inclusive and sustainable development.

We wish you a fruitful and enriching symposium experience filled with stimulating discussions, new insights, and meaningful connections. Together, let us make a lasting impact and pave the way for a sustainable and prosperous future for the plantation industry.

Prasad Dharmasena (PhD, MSc)
Editor-in-Chief
International Symposium on Sustainable Plantation Management

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Dr. J.A. Sumith

Registrar of Pesticides

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Sri Lanka

USE OF MORINGA (*Moringa oleifera* L.) LEAF EXTRACT AS A FOLIAR APPLICATION IN PEPPER (*Piper nigrum* L.) NURSERIES

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ABSTRACT

A field experiment was carried out at the Central Research Station, Department of Export Agriculture, Matale, Sri Lanka to study the effect of moringa (Moringa oleifera L.) leaf extract (MLE) as a foliar application on shoot and root growth of pepper (Piper nigrum L.) planting material. Four-potting media were used. This experiment was laid out in a Randomized Complete Block Design (RCBD) with three replicates. Foliar application of MLE was initiated at two weeks after planting of single node cuttings. Each plant was sprayed with 25 ml of 10% MLE and the growth performance was recorded at 2, 4, and 6 weeks after planting. The results showed that foliar application of MLE had a significant ($p < 0.05$) effect on tested parameters of pepper planting material over the control experiment. 10% MLE foliar application at two weeks interval increased fresh weight and dry weight of shoots, fresh weight and dry weight of roots, root length and number of roots. The recommended potting media by the Department of Export Agriculture namely topsoil: sand: coir dust: cow dung in the ratio of 1:1:1:1, reported a significant ($p < 0.05$) effect on shoot height, number of leaves and leaf area in pepper plants. Therefore, small scale farmers can use 10 % MLE as a low – cost and environmentally friendly foliar application to boost healthy growth of pepper plants in the nursery.

Keywords: Foliar application, Moringa leaf extract, Pepper cuttings, Plant growth, Potting media

INTRODUCTION

Pepper (*Piper nigrum* L.) is one of the major export agriculture crops in Sri Lanka. It is known as 'the king of spices' In Sri Lanka, pepper is cultivated in an area of 42,989 ha (DEA,2018). Mostly it is cultivated in the low and mid country, wet and intermediate agro-climatic zones as a monocrop or intercrop with tea and coconut plantations. Among the spices, pepper is second only to cinnamon in terms of foreign exchange earnings to the country. The world market demand for black pepper and its value-added products have been increased annually. The spiciness of black pepper is due to the chemical 'piperine'. Sri Lankan black pepper contains a higher amount of 'piperine' influencing a premium price in the international spice trade.

Pepper grows successfully between 20° North and 20° South of equator and from sea level up to 1500 m. It is a plant of humid tropics, requiring 2000-3000 mm of annual rainfall, tropical temperature and high relative humidity with little variation in day length throughout the year. Pepper does not tolerate excessive heat and dryness. Optimum soil temperature for root growth is 26° and 28°C (Wahid and Sitepu, 1987).

According to Export Development Board, Sri Lanka ranks at fifth place in terms of area under pepper cultivation after India, Indonesia, Vietnam and Brazil, and seventh place in terms of production, with a world share of 5.7%. Also, Sri Lanka is the fifth largest exporter of black pepper, after Vietnam, Brazil, Indonesia, and India. However, productivity levels in the industry remain low, despite improvements seen over the years. Pepper can be propagated by different ways, but mainly by cuttings. Orthotropic, plagiotropic and single or double nodal cuttings can be used as planting materials. Seed propagation often results in genetic variation while other methods of black pepper propagation are slow and time consuming (Atal and Banga, 1962). So, plant production by using orthotropic branch cuttings is a common practice of black pepper.

One of the constraints to pepper cultivation in Sri Lanka is lack of sustainable production. This is due to poor plant growth and low production. Good quality pepper planting material produces healthy pepper plants with better plant growth. Quality of pepper planting material could be improved by using proper potting media and fertilizer application. Plant hormones can be used to increase plant growth and yield of most of the crops because they influence every phase of plant growth and development. Traditionally, there are five groups of growth regulators which are listed: auxins, gibberellins, abscisic acid, ethylene and cytokinins (Prosecus.P.,2006). Cytokinins enhance shoot and root growth. Zeatin is one of the most common forms of naturally occurring cytokinin in plants. Reports revealed that fresh *Moringa oleifera* leaves have been shown to have high zeatin content (Mvumi Culve *et al.,* 2012).

Moringa leaf extract sprayed onions, bell pepper, soyabeans, sorghum, coffee, tea, chilli, melon and maize, showed an increase of yields (Fuglie, 2000). This leaf extract is low-cost and environmentally friendly (Noaman *et al.,* 2010). However, no studies have been reported on the effect of moringa extract on pepper planting material production.

Research Problem

Proper fertilizer is necessary for sustainable production of pepper and to improve the quality of pepper planting material. Nutrients can be applied through foliar application. Foliar application is feeding the plants by liquid fertilizer directly to the leaves. It causes low potential to damage plant roots than other conventional methods of fertilization. Foliar applications may be organic or inorganic. Inorganics are expensive and continuous application leads to reduction in yield and environmental pollution (Haji Sunarpi *et al.,* 2019) Use of organic materials could be an effective way and low-cost technology to increase the crop yield, especially by small-scale farmers without polluting the environment. It tends to reduce the application frequency of inorganic fertilizer to increase the crop yield during the cropping season. MLE can be used as a bio stimulant and it contains macro and micronutrients, amino acids, ascorbic acids, minerals and growth enhancing principles (Makkar *et al.,* 2007) such as hormone of the cytokinin type. Therefore, this study was conducted to study the effect of application of MLE as a foliar application on shoot and root growth of pepper (*Piper nigrum* L.) planting material with different potting media at nursery stage.

MATERIALS AND METHODS

The study was carried out at the Central Research Station, Department of Export Agriculture, Matale. The experiment consists of two factors with eight treatments. Different potting mixtures and with and without application of the same concentration level of MLE are the two factors. Treatment combinations are shown in Table 1.

Table 1: Treatments and treatment combinations in the experiment

Treatments	Treatment combinations
T1	topsoil: sand: coir dust: cow dung (1:1:1:1) with 10% MLE
T2	topsoil: sand: coir dust: cow dung (2:1:1:1) with 10% MLE
T3	topsoil: sand: coir dust: cow dung (1:1:1:1/2) with 10% MLE
T4	topsoil: sand: coir dust (1:1:1) with 10% MLE
T5	topsoil: sand: coir dust: cow dung (1:1:1:1) with water
T6	topsoil: sand: coir dust: cow dung (2:1:1:1) with water
T7	topsoil: sand: coir dust: cow dung (1:1:1:1/2) with water
T8	topsoil: sand: coir dust (1:1:1) with water

Nursery media was prepared by using topsoil, sand, cow dung, and coir dust as per the ratios given in Table 1 and filled into 8’ x 5’ polythene bags. Healthy, vigorous, and pest and disease-free single node cuttings were taken from the traditional variety ‘BD MN 4/6‘using Bamboo Rapid Multiplication System. Cuttings were treated with Captan fungicide. The lower node was buried in the polythene bag and the plants were immediately watered. The pots were kept in propagators to induce shoot and root growth (Fig. 1). Propagators were opened after one month period and one week after opening, MLE was applied.

(a) **(b)** **(c)** **(d)**

Figure 1: Preparation of pepper cuttings (a) single nodal pepper cuttings; (b) cutting planted in a polythene bags; (c) plants arranged in blocks; (d) plants inside a propagators

Young moringa leaves of about 100 g were taken into a mortar with a pinch of water (10 ml/ 100 g fresh material) and ground them with a pestle. The juice was extracted by applying hand pressure and filtered through a cheesecloth. The solution was re-filtered using No. 2 Whatman filter paper (Fig. 2). Following the method developed by Fuglie (2000), the extract was diluted with distilled water at the required concentrations (10%) and was sprayed directly onto pepper plants. The extract was used within five hours from cutting and extracting. The extract prepared was stored at 0ºC and only taken out when needed for use. An amount of 25 mL (application rate) of the moringa leaf extract was applied per plant. Hand sprayers were used to spray the extract.

(a) **(b)** **(c)**

Figure 2: Preparation of Moringa leaf extract and application (a) Young moringa leaves (b) Extraction of juice; (c) Moringa Leaf Extract (MLE)

Plant height, no. of new leaves, root length, root volume, no. of roots, leaf area, fresh weight of shoots, dry weight of shoots, fresh weight of roots, dry weight of shoots, soil pH and electrical conductivity of soil were recorded as observations after one month of planting. Data were collected at two weeks interval.

Shoot height and root length were measured by using a tape. Number of new leaves of the plant was counted and leaf area was measured by grid method. Number of leaves were counted which arisen from cutting surface. Shoot fresh weight was measured by using electronic balance. Root dry weight was obtained by putting into oven and drying at 60 ^{0}C until the weights of roots became constant. root fresh weight was measured by using electronic balance. Root dry weight was obtained by putting into oven at 60^{0}C temperature until the weights of roots became constant. Root volume was measured by inserting the root in a measured volume of water and the increased volume was considered as root volume.

The experimental design was a two-factor factorial design under a Randomized Complete Block Design (RCBD) with three replicates. The two factors used were potting media with four levels and with /without use of Moringa Leaf Extract.

Table 2: Levels of Potting media with different ratios

Levels	Potting media	Ratio
A	Topsoil: sand: coir dust: cow dung	1: 1: 1: 1
B	Topsoil: sand: coir dust: cow dung	2: 1: 1: 1
C	Topsoil: sand: coir dust: cow dung	1: 1: 1: ½
D	Topsoil: sand: coir dust	1: 1: 1

The collected data was statistically analyzed to find the significance difference between the treatments using STAR software in two -way ANOVA procedure. Data were analyzed using the analysis of variance (ANOVA) technique to evaluate the differences among treatments, and the means were separated using the least significant difference (LSD) at a significance level of 0.05 (Gomez and Gomez, 1984)

RESULTS AND DISCUSSION

During the experimental period, the direct sunlight, temperature and relative humidity at the experimental site, were 130 - 290 μmol m $^{-2}$ s $^{-1}$, 28°C – 32°C and 65% - 75% respectively.

It was observed that the potting media significantly influenced ($p < 0.05$) the shoot height in the 2nd, 4^{th,} and 6th weeks after planting. Potting media A which consists of topsoil: sand: coir dust: cow-dung in the ratio of 1: 1: 1: 1 had the highest shoot height in the 2nd week (9.77 cm) followed by potting media D with top soil: sand: coir dust in the ratio of 1:1:1 (Table 2). The lowest shoot height of 7.88 cm was recorded in the potting media C with top soil: sand: coir dust: cow dung in the ratio of 1:1:1:1/2. In the 4th week, the highest shoot height of 12.41 cm was observed ($p<0.05$) in potting media A while the lowest shoot height of 7.81 cm was observed in the B. No significant difference was observed in shoot growth among other three potting media. In the 6th week, the highest shoot height (14.44cm) was observed in potting media A. The lowest shoot height was recorded in potting media C. The results cleared showed that potting media A had the highest shoot height in the 2nd (9.77cm) ,4th (12.41 cm) and 6th week (14.44cm).

Table 3: Mean number of shoot height in the 2nd, 4th, and 6th weeks

Potting media	Shoot height (cm)		
	2nd week	4th week	6th week
A	9.77[a]	12.41[a]	14.44[a]
B	6.66[b]	7.81[b]	10.21[b]
C	7.88[b]	8.88[b]	9.79[b]
D	8.04[ab]	8.94[b]	9.81[b]

Means of the same letter in a column are not significantly different at P < 0.05.

Based on the leaf production of pepper, it clearly showed that there was no significant difference between with/without MLE and no significant interaction effect between potting media and with/without MLE on number of leaves. However, effect of potting media significant on shoot height (Table 3). The highest number of leaves was recorded in the potting media A with topsoil: sand: coir dust: cow dung in the ratio of 1: 1: 1: 1 at 4th and 6th weeks (Fig. 3)

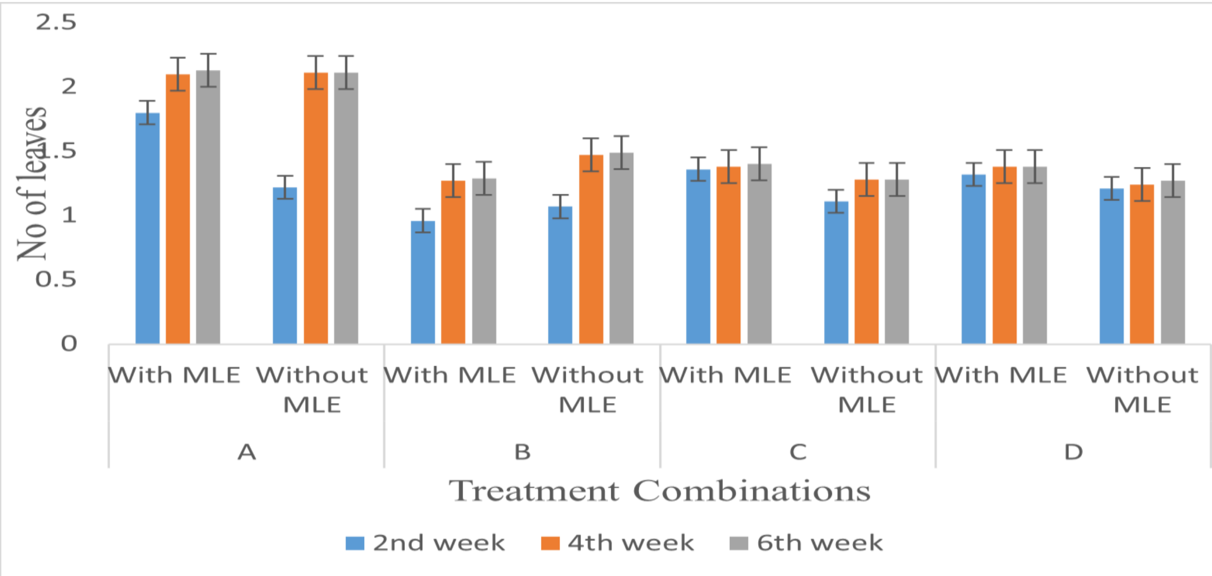

Figure 3: Mean value of no. of leaves

T1 treatment with topsoil: sand: coir dust: cow dung in the ratio of 1:1:1:1 with application of MLE showed the highest leaf area (13.3 cm^2) while T2 treatment with topsoil: sand: coir dust: cow dung in the ratio of 2:1:1:1 with application of MLE showed the lowest leaf area (7.26 cm^2) in the 2nd week. The highest leaf area of 28.45 cm^2 and lowest leaf area of 15 cm^2 was resulted in treatment T5 top soil: sand: coir dust: cow dung 1:1:1:1 without application of MLE and T8 topsoil: sand: coir dust in the ratio 1:1:1 without application of MLE respectively in the 4th week. According to Yusuff *et al*., (2020), on the efficacy of varying quantities of moringa extracts on leaf area of okra. It was evident that okra grown with moringa extracts had the highest mean value in terms of leaf area (205.52 cm^2).

The highest leaf area of 37.96 cm^2 was resulted in treatment T5 topsoil: sand: coir dust: cow dung 1:1:1:1 without application of MLE. The lowest leaf area of 19.54 cm^2 was resulted in treatment T8 topsoil: sand: coir dust in the ratio 1:1:1 without application of MLE respectively in the 6^{th} week.

Table 4: Mean value of leaf area

	Leaf Area (cm^2)		
Treatments	**2^{nd} week**	**4^{th} week**	**6^{th} week**
T1	13.30^{a}	25.92^{ab}	34.56^{b}
T2	7.26^{e}	16.25^{c}	25.33^{d}
T3	10.28^{b}	17.89^{c}	29.06^{c}
T4	8.32^{d}	14.27^{e}	20.04^{d}
T5	11.63^{ab}	28.45^{a}	37.96^{a}
T6	7.44^{e}	15.57^{d}	21.59^{d}
T7	8.59^{d}	15.66^{d}	24.74^{c}
T8	9.31^{c}	15.00^{d}	19.54^{e}

Mean of the same letter in a column are not significant at P < 0.05

A significant difference among potting media on leaf area of black pepper was observed in the 6^{th} week (Table 4). The highest leaf area was recorded in Media A (topsoil: sand: coir dust: cow dung in the ratio of 1: 1: 1: 1) with application of MLE (34.55 cm^2) and without application of MLE (37.96 cm^2). The lowest leaf area was recorded in the media D (topsoil: sand: coir dust in the ratio of 1:1:1 with application of MLE (20.23 cm^2) and without application of MLE (18.81 cm^2).

Table 5: Mean value of leaf area in 6th week in comparison with potting media

Potting media	Leaf Area (cm^2) in 6th week	
	With MLE	Without MLE
A	34.55[a]	37.96[a]
B	25.69[b]	21.22[b]
C	26.14[b]	20.48[b]
D	20.23[c]	18.81[b]

Mean of the same letter in a column are not significant at P < 0.05

Results of fresh and dry weight of shoots and roots showed that there was no significant difference between with / without MLE and potting media at α = 0.05 level (Table 5). The highest fresh weight of shoots of (7.03 g), dry weight of shoots (1.02 g) and fresh weight of roots (1.82 g) were observed in T1 treatment with topsoil: sand: coir dust: cow dung in the ratio of 1:1:1:1 with application of MLE.

This finding is in accordance with previous reports (Ali *et al.,* 2011; Abbas *et al.,* 2013 and Chattha *et al.,* 2015), which suggested that application of moringa leaf extract can improve the growth rate, number of leaves per plant, plant height, shoots and roots length, fresh weight and dry weight of shoots and roots of maize. Foidle (2001) revealed that spraying of moringa leaf extract to many field crops can strengthen plants, promotes vegetative growth and increases the weight of roots and shoots. This is in accordance with Hashish *et al.,* (2016) who reported that MLE increased the stem dry weight of *Alstonia scholaris* (timber plant). The highest dry weight of roots (0.15 g) was observed in T7 treatment with topsoil: sand: coir dust: cow dung in the ratio of 1:1:1:1/2 without application of MLE (Table 6).

Table 6: Mean value of fresh weight and dry weight of shoots

		Shoots		Roots
Treatments	Fresh weight (g)	Dry weight (g)	Fresh weight (g)	Dry weight (g)
T1	7.03[a]	1.02[a]	1.82[a]	0.13[ab]
T2	4.87[c]	0.93[b]	0.60[e]	0.06[b]
T3	4.59[c]	0.74[c]	0.71[e]	0.14[a]
T4	5.05[b]	0.97[ab]	1.25[b]	0.14[a]
T5	6.44[ab]	0.93[b]	1.43[b]	0.12[ab]
T6	4.65[c]	0.86[bc]	0.92[d]	0.14[a]
T7	4.57[c]	0.85[bc]	1.09[c]	0.15[a]
T8	4.41[cd]	0.85[bc]	1.05[c]	0.13[ab]

According to Fig. 4, 5 and 6, the root growth parameters namely root length, root volume and number of roots showed that there was no significant difference between with/without MLE and potting media. The highest root lengths of 17.97 cm and 19.78 cm were observed in T1, treatment with top soil: sand: coir dust in the ratio of 1:1:1:1 and application of 10 % MLE in the 4^{th} week and 6^{th} week respectively. The lowest root length (12.28 cm) was observed in the 4^{th} week in T5 treatment with top soil: sand: coir dust in the ratio of 1:1:1:1 without application of 10% MLE and 13.38 cm in the 6^{th} week was observed in T2 treatment with top soil: sand: coir dust in the ratio of 2:1:1:1 with application of 10% MLE.

In the data analysis of root volume, there was a significant difference in potting media A (1.82 cm^3) compared to other three potting media. The highest root volumes were was recorded in T8 treatment in 4^{th} week and 6^{th} week with topsoil: sand: coir dust in the ratio of 1:1:1 without application of MLE (1.58 cm^3) and T4 treatment topsoil: sand: coir dust in the ratio of 1:1:1 with application of MLE (2 cm^3).

Though statistically no significant difference was observed in the with and without application of MLE, the highest number of roots in 4th week and 6^{th} week was recorded in T1 treatment with top soil: sand: coir dust: cow dung in the ratio of 1:1:1:1 with application of MLE and T6 treatment with top soil: sand: coir dust: cow dung in the ratio of 2:1:1:1 without application of MLE was recorded as 16.3 and 11.5 respectively.

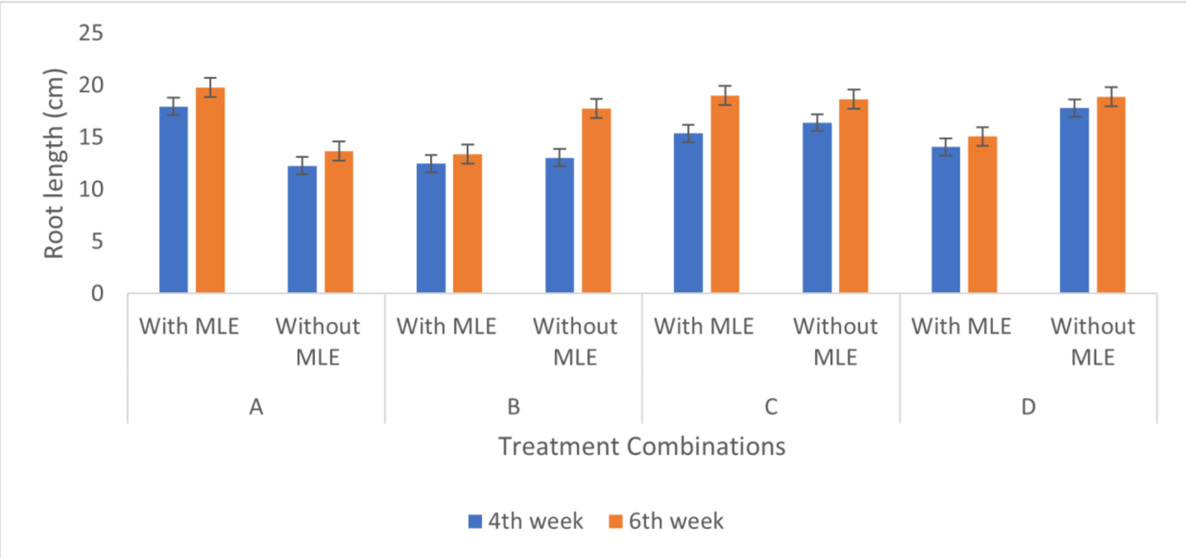

Figure 4: Mean value of root length

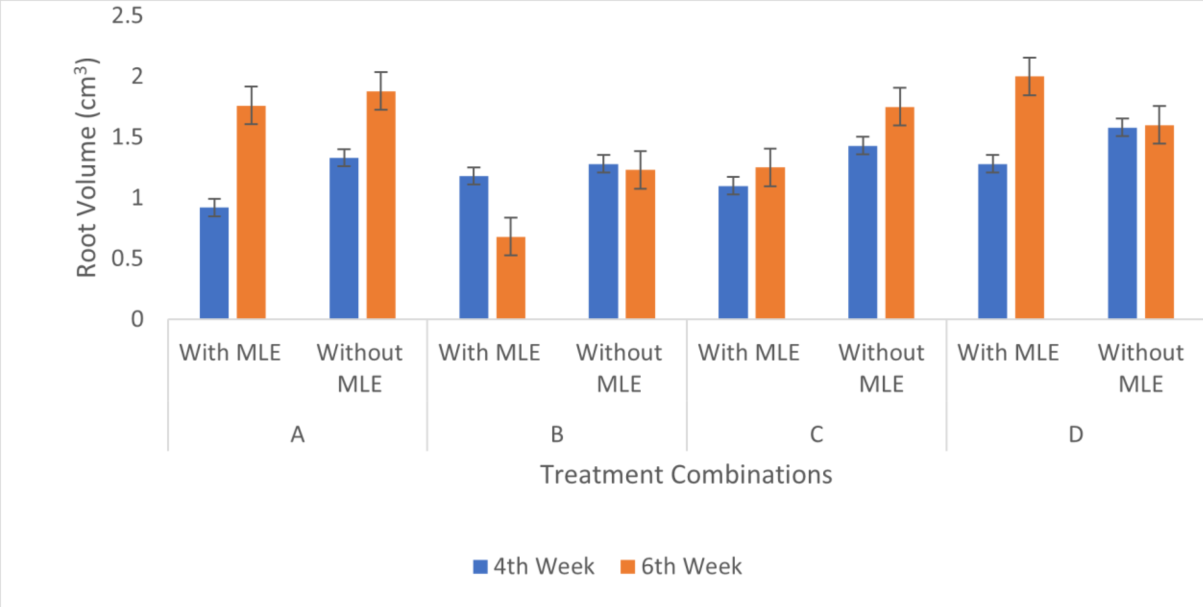

Figure 5: Mean value of root volume

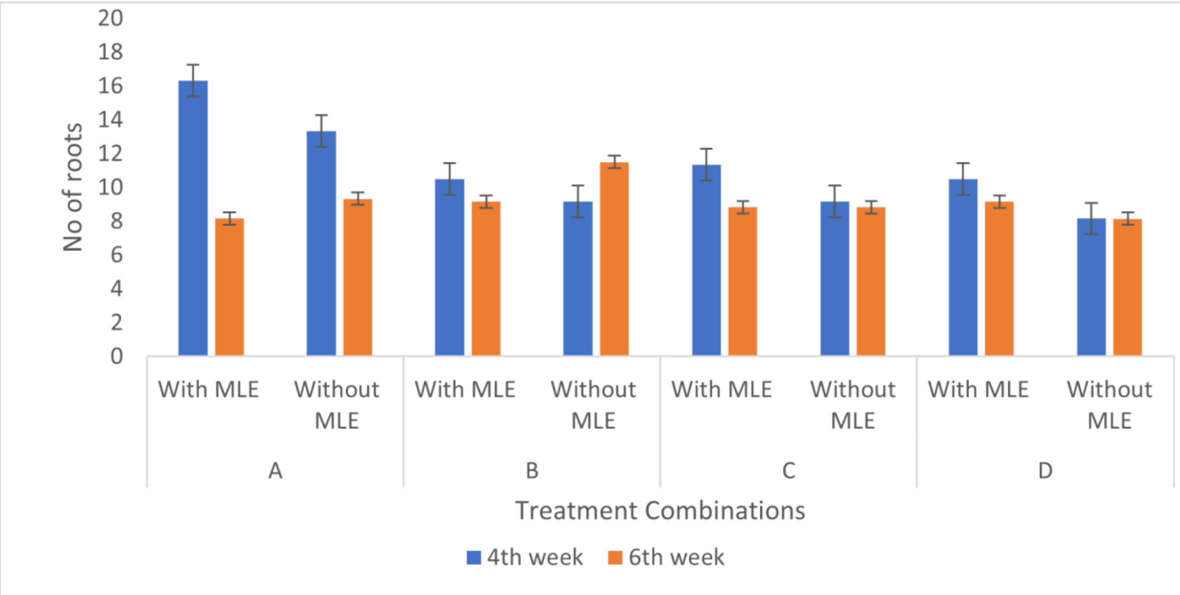

Figure 6: Mean value of number of roots

RECCOMENDATIONS AND CONCLUSION/S

The present study revealed that the potting media has a significant effect on shoot and root growth of pepper plant cuttings in the nursery. Among the four-potting media, potting media A which is recommended by the Department of Export Agriculture (topsoil: sand: coir dust: cow dung in the ratio of 1: 1: 1: 1), the had a significant effect on shoot height, number of leaves and leaf area in pepper plants. When considering the eight treatments, treatment T1 (topsoil: sand: coir dust: cow dung in the ratio of 1: 1: 1: 1 with 10 % MLE showed a significant effect on fresh weight and dry weight of shoots, fresh weight and dry weight of roots, root length and number of roots. Therefore, the application of topsoil: sand: coir dust: cow dung in the ratio of 1: 1: 1: 1 with 10 % MLE can be recommended to increase the shoot and root growth of pepper plants at the nursery stage. Further studies should be conducted to evaluate the effect of different concentrations and frequencies of moringa leaf extract as foliar application on shoot and root growth of pepper (*Piper nigrum* L.) planting material.

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EFFECTIVENESS OF A LOCALLY DEVELOPED ETHEPHON FORMULATION IN COMMERCIAL RUBBER PLANTATIONS

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ABSTRACT

Ethephon which is used as the yield stimulant in commercial rubber (Hevea brasiliensis) plantations is an essential agrochemical when practicing low intensity harvesting systems. Locally developed new water- based ethephon formulation has been tested against commercially available water based and oil based formulations in a commercial plantation to investigate its effectiveness to replace imported formulations that currently fulfill the local requirement.

Physiological yield determinant factors i.e. sucrose, thiol and inorganic phosphorous contents of the latex of trees applied locally developed ethephon formulation was comparable to existing formulations in the market. Latex thiol and inorganic phosphorous contents in acceptable ranges may ensure the long-term sustainability of the new ethephon formulation as a yield stimulant in rubber. The yield obtained with the application of new water-based formulation was comparable with the existing water-based formulation. However, oil-based formulation showed a significantly lower yield level than the new formulation.

Keywords: 2-choloroethylphosphonic acid, Exploitation, Hevea, Low intensity harvesting, Rubber, Stimulation, Tapping

INTRODUCTION

Rubber Research Institute of Sri Lanka had recommended several low intensity harvesting (LIH) systems to rubber plantations in Sri Lankan. To overcome the yield reducing due to lowering the intensity of harvesting, ethephon is used as a yield stimulant in varying dosages when practicing LIH (Gao *et al.,* 2018). Total requirement of the ethephon to Sri Lankan rubber plantation industry which is about 30MT/yr is imported in formulated form and CIF value of such amount is about 21 Mn LKR (1USD=350 LKR).

Being a whitish solid readily soluble in aqueous solutions and stable below pH 3.5 (Anon., 1987) ethephon could not be directly apply on plants. It is mainly formulated in soluble concentrate (SL) form are sold under several trade names corresponding to specific agricultural uses and generally applied as foliar sprays. However, to use with rubber, ethephon should be specially formulated to make more viscous enabling easy application on bark of tree whilst increasing the slow release properties. Therefore, it is usually mixed with an inert material i.e. methyl cellulose, starch, palm oil or a mixture of such materials to improve the desired characteristics to use with rubber tree.

Ethephon is a plant growth regulator with systemic properties, penetrates into the plant tissues, translocate and in the presence of water. It progressively decomposed to ethylene (Tseng *et al.,* 2000), which is a kind of plant hormone that affects the biochemical and physiological status of the tree resulting in high yields. Judicious application of ethephon with correct harvesting systems may only give long term sustainable yields.

Stimulation effect of ethephon depends on the length of cut and frequency of tapping or combination of them (Njukeng *et al.,* 2011). To overcome burning issues such as high cost of production, labour scarcity and high bark consumption rates in rubber plantations, nowadays rubber growing countries all over the world tend to adopt LIH systems (Karunaichamy *et al.,* 2001; Kewi & Sivakumaran, 1994; Rodrigo *et al.,* 2011; Xuehua *et al.,* 2004). In view of minimizing the cost involved, a formulation of ethephon was developed locally and the present study aimed to assess its suitability under commercial scale in Sri Lankan rubber plantations.

MATERIALS AND METHODS

Mature rubber field replanted in 2011 with RRIC 121 in Lower Division of Elston estate, Awissawella situated in Low country Wet Zone selected for testing the efficacy of new ethephon formulation. Tapping had been commenced since 2018 under rainguarded condition. Efficacy of the new formulation was tested using recommended protocol for S/2 d4 system in Sri Lanka with application of 2.5% ethephon, monthly except during wintering season maintaining 10 applications annually. The amount applied per tree per application was 0.6 g (Kudaligama *et al.,* 2022). Existing water-based (EWB) and oil based (EOB) ethephon formulations available in the local market were used for comparison as the controls. Treatments were tested using a randomized complete block design (RCBD). Three tapping tasks with 300-317 trees/tapper were allocated as replicates for each formulation.

Quantification of yield has been done in each tapping day. Latex volume collected from each plot has been measured and the dry rubber content of latex has been determined by the use of metrolac. With the knowledge of tapping days and the number of trees, yield per tree per year and yield per tree per hectare have been calculated.
Latex physiological parameters were tested during the period June-August, recommended as the favourable season for sampling. Latex samples were collected between 5th and the 35th minutes after tapping into vessels immersed in ice and taken

to the laboratory for analysis. Serum was extracted by coagulating the latex samples with 2.5% tricloroacetic acid (TCA). Standard test methods were used for analysis of sucrose (Scott and Melvin, 1953), inorganic phosphorous (Taussky and Shorr, 1953) and thiol (Boyne and Ellman, 1972). Plugging index was determined according to Milford, *et al.,* (1969) by using initial flow rate and total volume of latex obtained.

Performance of the new formulation was statistically compared with the existing formulations by performing an ANOVA using Genstat 16th edition followed by a mean separation.

RESULTS AND DISCUSSION

Ethephon is a plant growth regulator with systemic properties, penetrates into the plant tissues, translocate and in the presence of water it progressively decomposed to ethylene (Tseng *et al.,* 2000), which is a kind of plant hormone that affects the biochemical and physiological status of the tree resulting in high yields. Ethephon enhances yield by increasing latex regeneration, flow rate and duration of latex flow (Lacrotte *et al.,* 1985). Sucrose produced in plants by photosynthesis is the finally the basic molecule in all synthesis. In laticifers, sucrose metabolized into rubber (Bealing, 1976; Tseng *et al.,* 2000) hence sugar content in laticifers positively correlates with the yielding capacity of the tree (Lacrotte *et al.,* 1985; Mesquita *et al.,* 2006).

In all three years observed, trees applied new water based ethephon (NWB) formulation showed comparable dry rubber content (DRC) of latex with existing water based (EWB) and oil based (EOB) formulations. During the observed three years DRC did not fell below 30%. Despite of the type of formulation, DRC of latex harvested from trees applied three formulations were more of less similar. However, a considerable increase in DRC has been observed in the 3rd year (Fig. 1a).

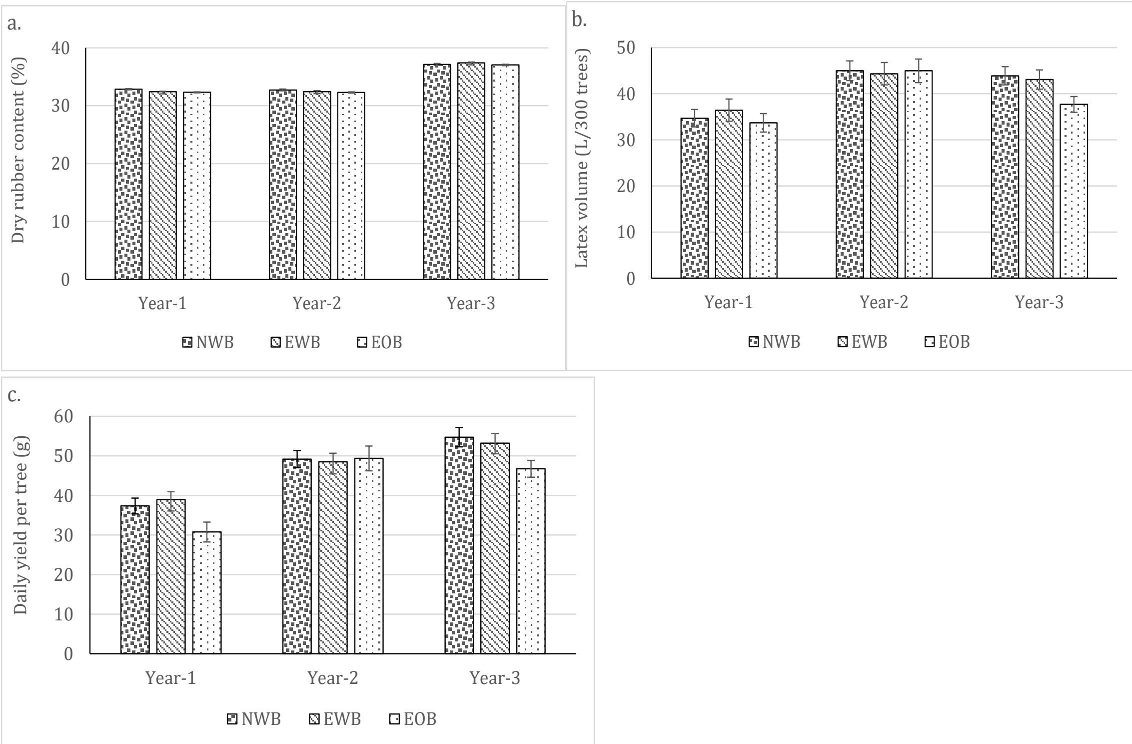

Figure 1: Average yield parameters of trees treated with new water based (NWB), existing water based (EWB) and existing oil based (EOB) ethephon formulations.

As expected, in the initial year after opening a tree for tapping, comparatively lower latex volumes were observed with all three formulations with no significant differences among the new and existing formulations. In the consecutive years an increase in latex volume has been observed. Though the comparable volumes have been achieved with application of three formulation during the 2nd year, it was significantly lower in trees applied EOB formulation in the 3rd year (Fig. 1b). Daily dry rubber yield harvested from a tree increased over the three years observed and NWB formulation has achieved statistically comparable average value with the EWB formulation. Though the EOB formulation had showed comparable dry rubber yield in the 2nd year, a significantly lower values had been observed during the 1st and the 3rd year (Fig. 1c). Over the three-year period observed average daily dry rubber yield obtained from a tree was 47.09, 46.90 and 42.31 g, respectively with application of NWB, EWB and EOB formulations. Average daily intake of a harvester (@300trees/task) which is the prime factor of determining the cost of production with application of NWB formulation was 14.13 kg whilst it was 14.07 kg with EWB formulation. However, with EOB formulation observed average intake of a harvester was 12.69 kg/day. Accordingly, NWB formulation has secured Rs.315/day, the average remuneration received for the extra harvest brought other than the norm compared to the EWB formulation. However, this was Rs.90/= lesser for the harvesters occupied in tapping blocks applied EOB ethephon. Average tapping days of tapping blocks applied NWB, EWB and EOB formulations were 73, 75 and 74, respectively.

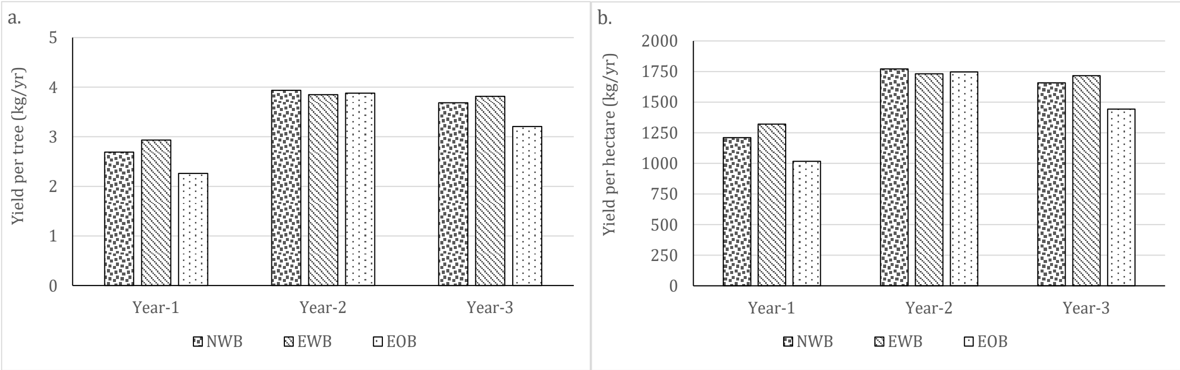

Figure 2: Average yield per tree and yield per hectare obtained annually during the observed period with application of new water based (NWB), existing water based (EWB) and existing oil based (EOB) ethephon formulations (@450trees/ha).

Being the initial year trees have been opened for tapping average yield per tree per year (YPT) calculated with the actual tapping days was considerably lower than the 2nd and 3rd year and this was similar for all three formulations (Fig. 2a). During the second year yielding capacity of trees was more or less similar. However, average YPT with EOB formulation during the 1st and the 3rd year showed a significant reduction when compared to the both water-based formulations (Fig. 2a). Similar variation has been observed with the yield per ha. per year (Fig. 2b).

Average sucrose content of latex of trees applied with NWB formulation was statistically comparable to the existing water based and oil based formulations used for comparison. Average latex sucrose content varied between 6.63 – 7.33 mM (Table 1) which is fair enough for a sustainable productivity in trees. Ethylene increase the activity of invertase; the key enzyme of glycolysis leads to enhance mevalonate production and ultimately the rubber biosynthesis (d'Auzac, 1989). Latex thiols consist of cysteine, methionine and glutathionine able to neutralize various forms of reactive oxygen species that harms membranes of latex organelles thus promote colloidal stability and flow of latex hence, directly correlate with the production of a tree (De Costa *et al.,* 2006; Jacob *et al*., 1986).

Table 1: Average latex physiological properties of trees treated with new water based (NWB), existing water based (EWB) and existing oil based (EOB) ethephon formulations.

	Sucrose content (mM)	Thiol content (mM)	Inorganic phosphorous content (mM)	Polyphenol content (mM)
NWB	6.63 [a] (±0.65)	0.20 [a] (±0.03)	10.37 [a] (±0.90)	1.00 [a] (±0.16)
EWB	6.57 [a] (±0.71)	0.24 [a] (±0.03)	9.68 [a] (±1.11)	1.01 [a] (±0.12)
EOB	7.33 [a] (±0.63)	0.21 [a] (±0.02)	9.99 [a] (±0.63)	1.04 [a] (±0.13)
n	25	25	25	25

Means with the same letters are not significantly different ($p \leq 0.05$). Figures in the parentheses are standard error.

Comparable latex thiol content in NWB ethephon with existing ethephon formulations reveals that absence of any unnecessary stress on the anabolic process of rubber biosynthesis (Table 1). Latex inorganic phosphorous may reflects its energy metabolism and significantly correlates with latex production in trees (Eschbach *et al.,* 1984). Ethephon stimulation activates the laticifer metabolism and as a result inorganic phosphorous content in latex increases (d'Auzac and Pujarniscle, 1959). Average inorganic phosphorous content in latex of trees applied NWB formulation was 10.37mM and it was comparable with the existing formulations marketed in Sri Lanka. This reveals that the energy needed for latex regeneration with new ethephon formulations is comparable with the existing formulations (Table 1).

Average yield obtained from trees applied NWB, EWB and EOB ethephon formulations were 3.44, 3.53 and 3.12 kg/yr. Accordingly, new and existing water based formulations has showed comparable productivity levels in the fields they have applied. Over the three year period the new water based formulation has shown 1546 kg/ha/yr productivity with a 43kg deficit annually over the value of EWB formulation without a significant difference. However, productivity with application of oil based formulation was significantly different which was 187 kg/ha/yr lesser than that of existing water-based formulation. Annually about 30MT of 2.5% formulated ethephon is imported for rubber plantations in Sri Lanka. If we could produce this quantity locally by importing active ingredient in 40% concentration, the quantity to be imported will reduce by sixteen times serving a considerable amount of foreign exchange. Further investigations are being carried out to assess long- term sustainability of the new ethephon formulation with advanced features developed by the Rubber Research Institute.

RECOMMENDATIONS AND CONCLUSION/S

Both the NWB and NOB formulations did not have any adverse effects on latex physiological parameters, flow parameters and raw rubber properties of the rubber tree latex. The NWB ethephon formulation showed the capability to achieve comparable yields to the existing formulation in commercial plantations. The NOB formulation exhibited a significantly higher stimulation effect, suggesting the possibility of achieving the same yield with a lower strength of ethephon in the NOB formulation. However, further investigations are necessary to validate this finding.

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USE OF BOTANICALS TO MANAGE TERMITE DAMAGE AT EARLY GROWTH OF SUGARCANE

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ABSTRACT

An experiment was conducted in the entomology laboratory and the Research farm of the Sugarcane Research Institute (SRI), Uda Walawe, Sri Lanka with the objective of determining potential pesticidal plant parts in dry form to manage termite damage during early plant growth phase of sugarcane. Termite species available in sugarcane ecosystem was identified by collecting soil samples randomly from sugarcane fields, preserving samples and observing head morphology and mandible shape of the soldiers. Preliminary choice test was conducted using 15 plant species with pesticidal effect. Among the15 plant species 8 species were selected for the field study such as, Wara (Astrocaryum vulgare), Ipil-Ipil (Leucenea leucocephala), Endaru (Ricinus communis), Neem (Azadirachta indica), Murunga (M. oleifera), Gliricedia (Gliricidia sepium), Papaya (C. papaya) and Gandapana (L. camara). Mature leaves of the selected pesticidal plants were collected, cleaned, and dried under room temperature. Three-budded sets of SL 96 128 sugarcane variety were planted at 1.37m spaced in 3 plots with 30 rows and 5m length. In each row, 200g of dried leaf layer was placed and seed sets were positioned on the dry matter layer. Later setts were covered with soil layer according to the standard management practices. Data on number of buds germinated damage and growth parameters were collected after one month from planting and data analysis was done using the analysis of variance (ANOVA) procedure. Five species of termites were identified i.e., Coptotermes ceylonicus, Heterotermes ceylonicus, Odontotermes ceylonics, Odontotermes redimani and Odontotermes horni. Highest set damage was recorded from M. oleifera, C. papaya and Azadirachta indica incorporated sugarcane rows. Lowest set damage to pesticidal plant treated sets was recorded from L. camara ($11.33^b \pm 2.18$) and L. leucocephala ($11.33^b \pm 1.76$) incorporated sugarcane rows. Highest germination recorded in L. camara ($39.33^a \pm 3.17$) and M. oleifera ($39^a \pm 1$) incorporated sugarcane rows. Dried leaf of L. leucocephala and L. camara were effective in managing termite damage. M. oleifera, C. papaya and A. indica showed higher attraction of termites to the field which case higher termite damage in the treated furrows.

Keywords: Damage, Effect, Pesticidal plants, Sugarcane, Termites

INTRODUCTION

Sugarcane (*Saccharum officinarum*) is a perennial grass belongs to family poacea. It is capable to store high concentrations of sucrose, or sugar, in the stem which is being used for processing sugar. Sugar is one of the major food commodities in Sri Lanka, and it has become an important sub-sector in the economy of the country. (Keerthipala, 2016). Currently, sugarcane is the only commercially cultivated crop to manufacture sugar in Sri Lanka. It is attacked by a range of insects, mainly including the tissue borers, sucking pests, cane grubs and termites. Losses due to these pests are estimated to be around 10% (Kfir *et al*., 2002; Goebel and Way, 2009). Termites are the most pestiferous insects in the tropics, causing damage to sugarcane. Over 2600 and 660 species of termites have been documented worldwide. They feed on dead organic materials such as crop residues, mulches, soil organic matter and live plant materials. The decreasing quantity of litter and soil organic matter, a preferred food source for indigenous termites, compels them to feed on pasture grasses, crops, and woody materials.

Synthetic termiticides have been used for a long time for controlling termites. Due to their residual effects, chlorinated insecticides pose a great hazard to the environment. In the hazardous nature and poor availability of chemical insecticides in the country, there is an increasing interest in naturally occurring toxicants from plants (Chang *et al.,* 2001).

Many plant extracts and essential oils act alternative sources of termite control agents because they constitute rich sources of bioactive chemicals. The botanical insecticides are generally insect specific and relatively harmless to non-target organisms including humans. They are also biodegradable and harmless to the environment (Jacobson, 1975). To manage termites, many African and Asian farmers use plant extracts such as neem, wild tobacco, dried chillies, wood ashes, and *Calotropis procera* (giant milkweed). Anti-termite chemicals found in nature and derived from locally accessible plants have the ability to control termite populations (Cynthia *et al.*, 2016) as these extracts contain alkaloids and flavonoids compounds that probably confer their insecticidal proprieties. (Ravaomanarivo *et al.*, 2014). Therefore, the present study was conducted to determine potential pesticidal plants to manage termite damage during germination and early plant growth phase of sugarcane.

MARETIALS AND METHODS

The experiment was conducted in the entomology laboratory and the Research farm of the Sugarcane Research Institute (SRI), Uda-Walawe, Sri Lanka (6^{o}N; 80^{o}E; Average temperature: 17-36ºC; Average rainfall: 1300-1600 mm; Elevation 76 amsl) during 1st of September to 1st of November 2022, The area is situated at low country dry zone, DL1a agro-ecological region Classification of soil in the area is Ranna series of reddish-brown earth (RBE (De Silva and De Costa, 2004) with sandy clay loam texture. The soil water contents at Saturation, Field Capacity (FC) and Permanent Wilting Point (PWP) was 30%, 20%, and 8%, respectively.

Identification of the available termite species and their damage in sugarcane plantations in Uda Walawe area. Soil samples were collected randomly from trial fields of the research farm, SRI with termite damage. Collected soil samples were carefully transported to the entomology laboratory. Termite specimens were collected and preserved in 70% ethyl alcohol. Among them soldiers were separated and then head morphology and mandible shape were observed through a binocular light microscope (KYOWA/ Tokyo) under 30 magnifications (WF x10 x 3). The species were identified according to the shape of head and protrusions on jaws of soldiers (SLSC,1977)

Identification of effective pesticidal plant for termite management

Study was conducted in two steps ie., preliminary study and field study.

Preliminary study

Considering the available literature and traditional agricultural knowledge in the Sri Lanka, 15 plant species (Table 1, Fig. 1) with Pesticidal effect were selected for the study. Availability of the plant, economic value, effect to the non-target organisms and effect to plants growth considered during selection.

Table 1: Plant species and part selected for the study

Scientific name	Common name	Plant part used
Azadirachta indica	Neem	Leaves
Astrocaryum vulgare	Wara	Leaves
Leucenea leucocephala	Ipil	Leaves
Gliricidia sepium	Gliricedia	Leaves
Ricinus communis	Endaru	Leaves
Moringa oleifera	Murunga	Leaves
Lantana camara	Gandapana	Leaves
Cinnamomum verum	Cinnamon	Leaves
Syzygium aromaticum	Cloves	Leaves
Cymbopogon citratus	Lemongrass	Leaves
Adhatoda vasica	Pawatta	Leaves
Piper betle	Bulath	Leaves
Helianthus annuus	Wild sunflower	Leaves
Citrus aurantifolia	Lime	Leaves
Carica papaya	Papaya	Leaves

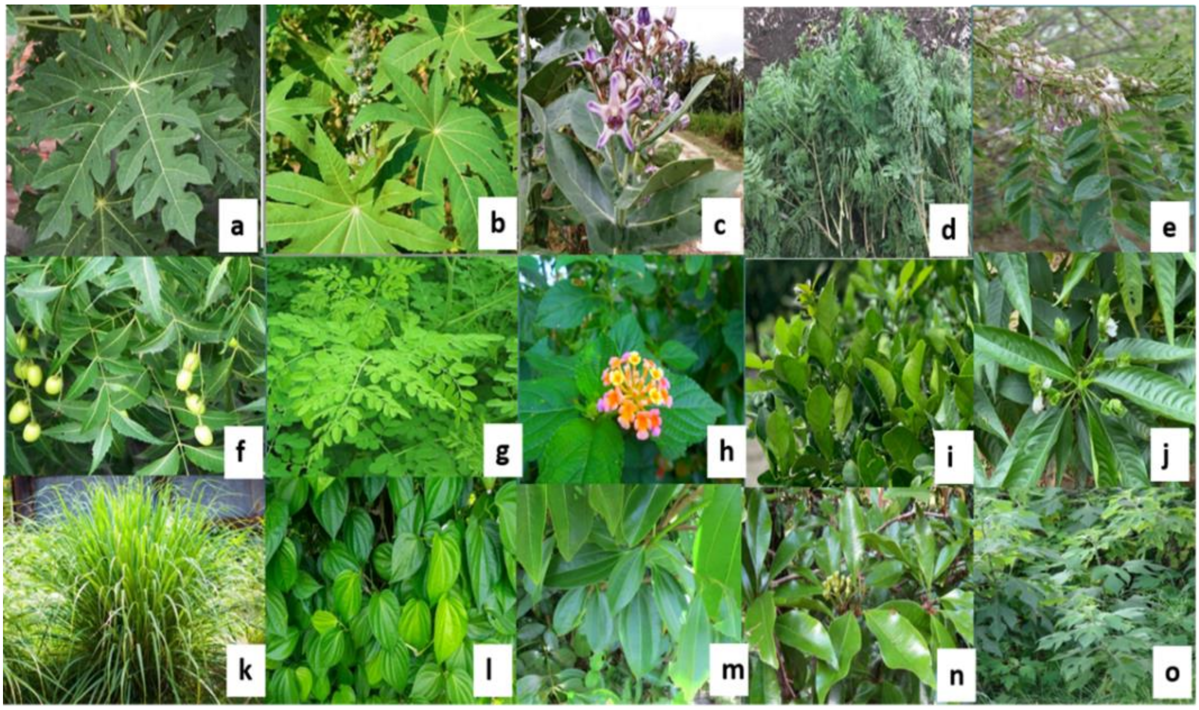

Figure 1: Selected pesticidal plants for the study
(a)Papaya, (b)Endaru, (c)Wara, (d)Ipil, (e)Gliricedia, (f)Neem, (g)Murunga, (h)Gandapana, (i)Lime, (j)Pawatta, (k)Lemongrass, (l) Bulath, (m)Cinnamon, (n)Cloves, (o)Wild sunflower

Preparation of the treatments

Mature leaves of the selected pesticidal plants were collected from the research farm of the SRI. Leaves were cleaned and separately kept in a clean place in a thin layer for 2 weeks period to dry under room temperature. Leaves were mixed and turned upside down for proper drying and to avoid mould formation. Dried plant leaves were then chopped using hand and stored in polythene bags until use (Fig. 2)

Figure 2: Experimental set-up of preliminary study

Shaded place under a tree near a termateria was selected for the study and location was weeded and wetted to provide high RH condition to attract termites. Wet cow dung and few sugarcane stems were distributed at the middle of the location which is highly attractive for termite. Just after one week, the termite colonisation occurred in all 15 treatments with control, around the colony from a 20cm distance in a circular manner. Similar distance kept between two treatments and treatments were randomised in the circle. Set up was replicated three times and kept undisturbed for one week period to proceed the infestation.

i. After one week period, each set with different treatment were uprooted carefully and following data were recorded. Number of live termites on or near the set
ii. Volume of damage

Recorded data were compared using the analysis of variance (ANOVA) procedure and the mean separation was done using the Duncan Multiple Range in SAS 9.0v software to identify most effective treatments/ plant material for termites.

The field studies
The Most effective 8 plant species were selected for the field study. The land preparation was done according to the recommendation. Wet cow dung was applied along the furrows after land preparation to attract termites to the test plots and even distribution throughout the field. Then field was carefully irrigated and left undisturbed for one week period for infestation.

Pre count of the termite population in the trial plots were taken after one week from cow dung application. In here soil samples from the plots were collected separately in zigzag pattern. Number of termites available in each sample was counted carefully and recorded. Population data were compared using the analysis of variance (ANOVA) procedure and the mean separation as done using the DMRT in SAS 9.0, software to confirm even distribution of the termite in test field.

Dry leaf matter of eight pesticidal plants selected from preliminary test was used as treatments in the field study. The field experiment was arranged as randomized complete block design (RCBD) with eight treatments, two control (Prefronil and no Dry leaf matter) and three replicates (Table 2).

Table 2: Experimental design/ Field layout (Top to bottom)

Rep 1	1m	Rep 2	1m	Rep 3
Wara		Endaru		Murunga
Ipil		Gliricedia		Control
Endaru		Prefronil		Gandapana
Neem		Gandapana		Gliricedia
Murunga		Ipil		Endaru
Gliricedia		Control		Papaya
Papaya		Neem		Prefronil
Gandapana		Papaya		Wara
Prefronil		Wara		Ipil
Control		Murunga		Neem
5m		5m		5m

Measurements were taken from 4 weeks after planting as following,

To estimate termite damage,

a. Number of buds germinated
b. Level of bud damage (volume)

To estimate effect of treatment on growth of the treated plants,

a. Height of the plant
b. Number of leaves
c. 3rd leaf length
d. 3rd leaf width.

Other pest damages (Shoot borer, Grubs etc.) also observed during the study period to determine effect of treatments for other pest attractions. Statistical data analysis was done using the analysis of variance (ANOVA) procedure and the mean separation as done using the Duncan Multiple Range Test (DMRT) in SAS 9.0v software.

RESULTS AND DISCUSSION

Five species of termites were identified from the samples collected in sugarcane plantations in Uda Walawe area, consider the shape of their head, mandibles and labrum. They were *Coptotermes ceylonicus, Heterotermes ceylonicus, Odontotermes ceylonicus, Odontotermes redimani and Odontotermes horni* (Table 3 and Fig. 3).

Table 3: Identification criteria of termite Species.: Head shape, Mandible Character and Labrum Character

Termite species	Head shape	Mandible Character	Labrum Character
Coptotermes Ceylonicus	Oval shape	Noprominent teeth	Oval shape
Heterotermes ceylonicus	Long rectangular	No teeth	Prominent labrum
Odontotermes ceylonicus	Round shape and Large	No teeth and no mandibles	Not Prominent
Odontotermes redimani	Conical shape	Teeth on both mandibles	Not Prominent
Odontotermes horni	Oval shape	Tooth has only on left mandible	Not Prominent

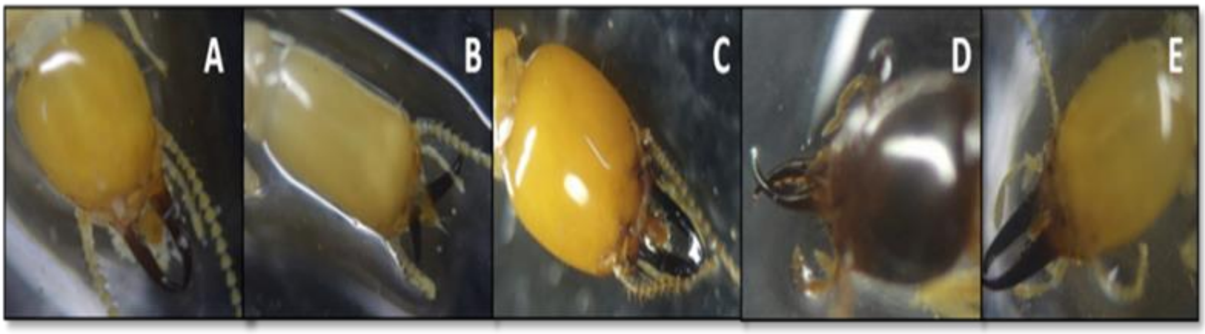

Figure 3: Head structure of collected termite species collected from Uda Walawe
(A) Coptotermes ceylonicus,* (B) *Heterotermes ceylonicus,* (C) *Odontotermes ceylonicus,* (D) *Odontotermes redimani and (E*) *Odontotermes horni

Several studies have reported these species in sugarcane ecosystem. Bandara (2013) have reported all these five species in Uda Walawe area. Kumarasinghe, (2003) has identified three termite species such as *Odontotermes ceylonicus, Odontotermes redimani*, and *Odontotermes horni*, which severely affect the rain-fed sugarcane plantations at Pelwatte, Sevanagala and Uda Walawe. He has also listed six species of termites as pests of sugarcane in Sri Lanka as *Odontotermes ceylonicus, Heterotermes ceylonicus, Odontotermes redimani*, *Odontotermes horni*, *Coptotermes ceylonicus* and *Nasutitermes ceylonicus*in 2008 and 2012.

Identification of effective pesticidal plants for termite management

Considering the available literature on pesticidal characters of locally available plant species, 15 species was considered in the study (Table 4). Availability of the plant material, cost effectiveness, effect to favourable organisms and effect to plants growth were the factors considered mainly.

Preliminary study

According to the results of choice test no termite damage recorded in *Medicago sativa, Ricinus communis, Adhatoda vasica, Piper betle, Syzygium aromaticum, Syzygium aromaticum* and *Lantana camara* treated seed sets (Table 4). Miner termite damages were recorded on *Cinnamomum verum, Citrus aurantifolia* and *Gliricidia sepium*. But they were not significantly different from treatments associated with no damage. *Carica papaya* (11.7^{a}±0.43) incorporated sets showed highest termite damage followed by *Azadirachta indica* (10.13^{b}±0.46) and *Moringa oleifera* (9.83^{b}±0.44).

Table 4: Volume of the seed cane destroyed by the termite consuming

No	Plant species	Damage volume (cm^3)	No	Plant species	Damage volume (cm^3)
1	*Astrocaryum vulgare*	2.13^{fg}±0.13	9	*Helianthus annuus*	7.5^{c}±0.61
2	*Leucenea leucocephala*	0^{h}±0	10	*Cinnamomum verum*	0.33^{h}±0.33
3	*Ricinus communis*	0^{h}±0	11	*Citrus aurantifolia*	3^{h}±0.05
4	*Azadirachta indica*	10.13^{b}±0.46	12	*Piper betle*	0^{h}±0
5	*Moringa oleifera*	9.83^{b}±0.44	13	*Syzygium aromaticum*	0^{h}±0
6	*Gliricidia sepium*	1.23^{gh}±0.69	14	*Lantana camara*	0^{h}±0
7	*Carica papaya*	11.7^{a}±0.43	15	Control	5.7^{d}±0.79
8	*Adhatoda vasica*	0^{h}±0			

Values within a column followed by a common letter are not significantly different at P=0.05, according to DMRT.

Effect of pesticidal plant parts for set damage

Highest set damage to pesticidal plant treated sets was recorded from *Moringa oleifera* (Murunga) leaf incorporated sugarcane rows followed by *Carica papaya* (Papaya) and *Azadirachta indica* (Neem) incorporated sugarcane rows. Damages recorded were 18.33^{a}±1.66, 17.66^{a}±2.33 and 17.33^{ab}±1.45 respectively. They were not significantly different from untreated control where the damage was 17.33^{ab}±1.45.

Lowest set damage to pesticidal plant treated sets was recorded from *Lantana camara* (Gandapana) leaf incorporated sugarcane rows followed by *Leucenea leucocephala* (Ipil Ipil) incorporated sugarcane rows. Damages recorded were 11.33^{b}±2.18 and 11.33^{b} ±1.76 respectively. They were not significantly different from treated control, Fipronil (current recommendation for termite control in sugarcane) where the damage was 11.33^{b}±1.76.

Effect of pesticidal plant parts for germination

Highest germination (Table 5) recorded in *Lantana camara* (39.33^{a}±3.17) and *Moringa oleifera* (39^{a}±1) incorporated sugarcane rows. Germination of both species was not significantly different from treated control, Fipronil (40.33^{a}±2.02). Lowest germination recorded in *Astrocaryum vulgare* (30^{d}±2.08) followed by untreated control.

Table 5: Germination, damage, and growth parameters of the Seed sets

Plant species	Germination count	Damage mean count	Height (cm)	3rd leaf length (cm)	Leaf No	3rd leaf width (cm)
Astrocaryum vulgare	30^{d}±2.08	12.33^{ab}±1.33	16.06^{a}±1.68	61.48^{a}±8.91	5.03^{a}±0.06	2.63^{a}±0.15
Leucenea leucocephala	37.66^{ab}±1.52	11.33^{b}±1.76	14.08^{a}±0.69	51.08^{a}±2.04	4.5^{a}±0.11	2.35^{a}±0.10
Ricinus communis	37^{ab}±1.15	14^{ab}±0.57	14.83^{a}±0.18	58.10^{a}±0.90	4.6^{a}±0.20	2.42^{a}±0.04
Azadirachta indica	34.66^{bc}±2.18	17.33^{ab}±1.45	14.55^{a}±0.42	54.85^{a}±4.02	4.76^{a}±0.23	2.52^{a}±0.17
Moringa oleifera	39^{a}±1	18.33^{a}±1.66	14.11^{a}±1.15	51.63^{a}±5.86	4.73^{a}±0.08	2.54^{a}±0.09
Gliricidia sepium	36.66^{ab}±0.6	15.33^{a}±2.33	13.79^{a}±1.15	52.34^{a}±1.92	4.63^{a}±0.26	2.5^{a}±0.05
Carica papaya	31.66^{cd}±1.2	17.66^{a}±2.33	14.59^{a}±0.57	54.60^{a}±7.62	5^{a}±0.2	2.55^{a}±0.19
Lantana camara	39.33^{a}±3.17	11.33^{b}±2.18	13.8^{a}±0.70	57.5^{a}±1.24	4.83^{a}±0.14	2.46^{a}±0.03
prefronil	40.33^{a}±2.02	11.33^{b}±1.76	14.55^{a}±0.65	55.92^{a}±3.27	4.86^{a}±0.03	2.53^{a}±0.06
Control	30.66^{cd}±2.33	17.33^{ab}±1.45	14.61^{a}±0.20	57.14^{a}±0.97	4.83^{a}±0.08	2.58^{a}±0.14

Values within a column followed by a common letter are not significantly different at P=0.05, according to DMRT.

Effect of pesticidal plant parts for growth parameters

The height, length of the third leaf, leaf number and the width of the leaf number in related to the treatment applied were not significant. According to the results, dried leaf of *Leucenea leucocephala* (Ipil Ipil) and *Lantana camara* (Gandapana) are effective in managing termite damage. The leaves and seeds of Ipil-Ipil plant include several chemicals i.e. terpene, flavonoids, cumarin, sterol, ficaprenol-11, scualene, lupeol, cis-cumaric acid, pheophytin-a, pheophorbide a-methyl ester, and aristophyll-C (Pascual and Penaflorida, 1979; Wardatun *et al.*, 2020) and among them several had pesticidal properties.

Insecticidal and nematicidal activities recorded in novel mimosine derivatives viz., High nematicidal activity was detected in mimosine and strong insecticidal properties were present in mimosinol and its derivatives (Nguyen, *et al.*, 2015). Furthermore, mimosine is responsible for the bio-herbicidal effects (Ilham *et al.*, 2015). The high larvicidal activity was demonstrated by a leaf extract of L. leucocephala in n-hexane against *Aedes aegypti* larvae (Lusiyana, *et al.,* 2018). Abdullah and Hossain (2006) urea-N fertilizer dosage supplemented with Ipil-Ipil tree litter produce good yield while minimizing insect prevalence in the rice field viz. green leafhopper, brown plant hopper, rice bugs, leaf folder and stem borers.

Lantana camara L. is a big shrub evergreen scrambling plant ad different parts of lantana weed have various allelochemicals such as carbohydrates, flavonoids, and tannins. Such chemicals or compounds enhance or reduce growth and yield of different crops. Overall, the growth parameters and photosynthetic pigments were increased with increase leaf extract concentration till 15%. Therefore, the most effective treatment was 15% as it gave the greatest increases in the studied growth parameters. In current study Lantana incorporated setts showed higher rate of germination confirming the above fact.

Lantana camara contains lantadene, a toxin poisonous to animal livers. The flavonoid groups were termed as Lantaden A and B (Kasmara *et al.*, 2018). The main phytochemical groups found in various parts of *L. camara* are essential oils, flavonoids, phenolic compounds, proteins, carbohydrates, glycosides, alkaloids, phenyl ethanoid, quinine, iridoid glycosides, saponins, oligosaccharides, steroids, triterpenes, sesquiterpenoides, and tannins. Its leaves contain essential oil. Isorhamnetin, Quercetin, oleanolic acid, sitosterol pomonic acid, lantadene A, verbacosides, camaric acid, lantanoside, octadecanoic acid, linaroside, docosanoic acid and palmitic acid are some of the major bioactive chemicals (Swamy, Sinniah and Akhtar, 2015). These allelopathic compounds are naturally present in the plant's leaves, stem, roots, and flowers (Baidoo, *et al.*, 2017). A phytochemical screening of *L. camara* ethanolic leaf extract showed the presence of phenolic acid, alkaloids, flavonoids, carbohydrates, cardiac glycosides and steroid compounds (Etuh, *et al.,* 2021). The most effective organic solvents were methanol extracts with seven (7) phytoconstituents. While ethyl acetate and chloroform extracts only contained five phytocompounds, an acetone extract revealed the presence of six phytoconstituents. Results of this study is comparable with the several studies throughout the world. Five percent chloroform extract showed excellent termite mortality (Verma and Verma, 2006). Many compounds with insecticidal activity are found in *L. camara* (Baidoo, *et al.*, 2017). Other than to the termites, Lantana have been used for managing several pests including, *Musca domestica* (House fly), *Sitophilus oryzae* (Rice weevil), *Spodoptera litura* (Common cutworm) *Tribolium castaneum* (Red flour beetle) and *Callosobruchus chinensis* (Bean beetle). Lantana barks and leaves can exhibit antibacterial, larvicidal properties, fungicidal, and insecticidal effects, according to studies carried out in India (Rajashekar, *et al.,* 2014). Methanol extracts of *L. camara* leaves are fumigant and poisonous to *S. oryzae, C. chinesis, and T. castaneum*). *Moringa oleifera* (Moringa), *Carica papaya* (Papaya) and *Azadirachta indica* (Neem) showed higher attraction of termites to the field which higher termite damage in the treated furrows. It was recorded that *Moringa oleifera* leaf is high N source and moringa leaf induce seed germination when it incorporated as a fertilizer or pesticidal compound. Rasheed *et al.,* (2021) discussed that, Moringa leaf extract (MLE), is commonly used as growth enhancers and applied either as seed priming and/or foliar spray. These extracts exert positive impacts on plant growth and production with alterations in metabolic processes under different cultivation practices. Moringa rich in growth hormones, antioxidants, vitamins, and mineral nutrients. Moringa and sorghum water extracts (at specified concentrations) are very effective in improving plant growth and development. The use of MLE enhances seedling emergence and establishment, improves crop growth development, which improve crop productivity under stressful and benign environments. This may be the reason for higher germination rate of Moringa treated plant rows in current study.

During current study Moringa dried leaf treatment was not effective over termites in sugarcane ecosystem. However, several studied on pesticidal effect of Moringa have confirmed management of different termite species. Omoregie *et al.,* (2018) confirmed that root extract of Moringa increase mortality of *Macrotermes bellicosus* soldiers significantly. The phytochemicals identified in the root were: alkaloids, phenols, flavonoids, tannins, glycosides, steroids, triterpenoids, saponins and anthraquinones. He has suggested that Moringa root extract useful for the control of *Macrotermes bellicosus* due to promising potency against the species. Okweche *et al.,* (2015) observed that *M. oleifera* seed extract recorded 95% mortality after 60h and 100% at 72 h on the wood termite *Cryptotermes cavifrons* Banks. Paiva *et al.,* (2010) reported insecticidal effect of *Moringa oleifera* extract on termites. Paiva *et al.,* (2010) reported that, *Moringa oleifera* seeds extraction at concentrations of 1.0 and 1.5mg/ml effective on workers and soldiers of *Nasutitermes corniger.* Therefore, further studies in pesticidal effect of Moringa on termites under Sri Lankan conditions are important. Seed and leaf extracts of *Carica papaya*, have pesticidal and larvacidal effect over several pest species. Phytochemical analysis contains secondary metabolites compounds of saponin, flavonoid and triterpenoid. *Azadirachta indica* (Neem) showed higher attraction of termites to the field which case higher termite damage in the treated furrows. However, it is associated with various components include quercitin, other limnoids, oleic and palmitic acids, Nimbin, Nimbinin, and Nimbidin. Azadirachtin is currently regarded as neem's primary insecticidal agent. Pesticidal qualities of Azadirachtin includes antifeedant, attractant, repellent, and growth disrupting against a variety of insect pests. The seeds, flowers, fruit, leaves, twigs, barks, and roots of the neem tree have all been studied, and the phytochemicals present in these parts have been determined to be the most promising for use as natural insecticides and medications (Massaguni and Latip, 2015). Neem tree leaves and seed extracts have been discovered to have pesticidal activities against more than 400 species of phytophagous insects in several laboratory and field investigations (Massaguni and Latip, 2015).

RECOMMENDATIONS AND CONCLUSION/S

Dried leaf of *Leucenea leucocephala* (Ipil Ipil) and *Lantana camara* (Gandapana) are effective in managing termite damage. *Moringa oleifera* (Moringa), *Carica papaya* (Papaya) and *Azadirachta indica* (Neem) showed higher attraction of termites to the field which higher termite damage in the treated furrows. Active ingredients of *Leucenea leucocephala* and *Lantana camara* and effective dosage for pesticidal plant materials should be studied further for developing termiticides product. Fertilisers and other agronomic products produced from Moringa, Papaya and Neem leaves should not incorporate or applied to crop fields in termite susceptible areas and further studied is required to identify the specific reason for the scenario.

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PRELIMINARY INVESTIGATION TO DETERMINE THE POTENTIAL OF USING RUBBER PROCESSING FACTORY EFFLUENT AS A NUTRIENT SOURCE FOR FOOD CROPS

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ABSTRACT

Raw rubber processing factories generate a considerable volume of Rubber factory processing effluent (RFPE). It is compulsory to treat the RFPE prior to discharge in to the environment which is an expensive process. The Objective of the study was to study the properties of RFPE followed by the preliminary study to understand the effect of effluent as a nutrient source on crops. Initially, collected effluent samples at different processing steps were analyzed for the major nutrient contents, metal ions and also the pH value. Then, an experiment was designed to investigate the effect of daily application of rubber factory fresh serum for greenhouse cultivation of Salad cucumber (Cucumis sativus L.) grown in soilless (coir) media. Treatments were designed with different ratios of Albert fertilizer 75% (T2), 50% (T3) and 25% (T4) combined with application of fresh serum. Albert fertilizer 100% (T1) and fresh serum only (T5) treatments were applied as positive and negative controls respectively. Growth and yield parameters of the plants were recorded. The greatest amount of nutrients was available in fresh serum collected from the coagulation tank while the nutrient levels were depleted in the latter processing steps including the metal ions. Fresh serum had low pH value. Therefore, the acidity was amended before applying to the crops. There was no significant difference in growth parameters among the treatments including the controls. T2, T3, T4 and T5 treatments gave significantly higher value of crop yield compared to T1. In conclusion, pH adjusted fresh serum has a nutrient value to be used regularly as a fertilizer supplement. This study opened a path for further studies on potential of fresh serum to be used as a nutrient source for agricultural crops.

Keywords: *Cucumis sativus L.*, Effluent, Fertilizer Plant Nutrients, Rubber

INTRODUCTION

Rubber industry is one of the major export industries, which plays an important role in the country's economy by generating export income and providing a livelihood for more than 500,000 people in the country (Anon, 2012). Raw rubber required by the rubber industry is manufactured locally in four forms namely Ribbed Smoked Sheet, Crepe Rubber, Centrifuged Latex and Technical Specified Rubber. All raw rubber processing factories generate a considerable volume of RFPE irrespective of the type of rubber manufactured. It is compulsory to treat the RFPE to meet the regulatory standards prior to discharge in to the environment (Anon, 2008). Previous studies have been conducted by scientists at RRISL on effluent as a nutrient source in rubber cultivation during nursery and immature stages (Samarappuli, 1992) and found a significant effect of effluent on the solubility of ERP (Eppawala Rock Phosphate) (Samarappuli, 1995) and further, reported that half of general fertilizer recommendation of N, K, Mg plus full recommendation of P by ERP has comparative effect to that of general recommendation (Samarappuli, 2002). International studies have also been conducted and showed the potential of land application of RPFE (Eifedivi *et al.,* 2012; Maliki *et al.,* 2020).

Research problem

Rubber Research Institute of Sri Lanka invented a cost-effective effluent treatment system for all types of RFPE generated in various types of raw rubber manufacturing factories in 1998 which was patented (Senevirathne,1998). It has been the widely accepted treatment system in the rubber plantation sector. This system is capable to treat the RFPE discharge into the ground water streams where 1: 8 dilutions is possible. With the increased concerns of the public on the environment and stringent regulations implemented by the authorities together with the depletion of ground water streams with adequate water flows, continuation with this treatment system has become questionable in future. At present, plantation companies have to spend huge cost for transport partially treated effluent water to the government approved central industrial wastewater disposal plants. In addition, high capital cost and operational cost have made this treatment system discourage its acceptance in the industry in the prevailing poor economic environment. At present, farmers seek substitutes for inorganic fertilizer as they are expensive. Organic fertilizer, Industrial wastes have become alternatives for inorganic fertilizer and are highly investigated for the purpose.

Therefore, it is worthwhile to carry out an investigation on potential of RFPE as a nutrient source for agricultural crops and the potential of its application for cutting down inorganic fertilizer requirement. This will consequently reduce the requirement of expensive waste water treatment practices while reducing the threat on the environment.

The objective of the study was to study the properties of RFPE followed by the preliminary study to understand the effect of regular application of effluent in combination with different ratios of inorganic fertilizer on the growth and yield of soilless grown salad cucumber in greenhouse condition.

MATERIALS AND METHODS

Evaluation of the properties of the RFPE

Eight crepe rubber producing factories were selected randomly representing traditional rubber growing areas for sample collection. Samples were collected from different stages of the production from coagulation tank to smooth milling in those factories. They were tested for major nutrient parameters N, P, K, Mg, metal ions: Zn, Fe, Mn, Cu, Pb and pH in the laboratory.

Fresh serum treatment on salad cucumber plants

An experiment was conducted to investigate the effect of rubber factory fresh serum (fresh effluent collected from coagulation tank) as a nutrient source for cultivation of Salad cucumber plants grown in soilless media (coir media) under a greenhouse environment. The salad cucumber hybrid *Cucumis sativus L.* which has a three months crop cycle developed specially for protected agriculture, was used as the crop *spp*. Daily application of liquid fertilizer (Albert solution with the nutrient content: 10.6% N, 9.3% P, 16.3% K, 11% Ca, 2.25% Mg, 35 mg/kg B, 35 mg/kg Cu, 660 mg/kg Fe, 130 mg/kg Mn, 140 mg/kg Zn and 20 mg/kg Mo) and effluent water was done according to the treatments. The fresh serum collected from the coagulation tank was stored in a trap tank for non-rubber particles to be trapped and the serum was filtered and then pH was tested. pH adjustments were done using 0.1 M NaOH before using for the study. Average requirement of 0.1 M NaOH was 4 ml per 1 liter of the fresh serum which is a negligible amount to result toxic effect of Sodium on plant growth.

Treatment application was started when plants are of 1 month age when reached the reproductive stage. Treatments were designed to find the effect of cutting down of Albert fertilizer while combining it with application of effluent water (Table1 and 2). The average total N content in the fresh serum (500 mg/liter) was considered when designing the treatments. It was assumed that about 50% of total N in the serum will be readily available for the plants and the volume of serum to be applied for compensating the reduced Albert fertilizer was calculated accordingly. Twenty plants per treatment were arranged in completely randomized design (CRD). Growth parameters of the plants and yield were recorded at regular intervals.

Table 1: Treatment combinations from 0 – 2 weeks of treatment application

Treatments	Percentage of Recommended Albert Solution	Volume of fresh serum
T1-	100%	0 ml
T2-	75%	150 ml
T3-	50%	300 ml
T4-	25%	450 ml
T5-	0%	600 ml

During this period normal recommendation of Albert solution is 1.5 g per plant dissolved in the ratio 1kg Albert mixture: 400 liters of water.

Table 2: Treatment combinations from 2 weeks of treatment application

Treatment	Percentage of Recommended Albert Solution	Volume of fresh serum
T1-	100%	0 ml
T2-	75%	200 ml
T3-	50%	400 ml
T4-	25%	600 ml
T5-	0%	800 ml

During this period normal recommendation of Albert solution is 2.0 g per plant dissolved in the ratio of 1kg Albert mixture: 400 liters of water.

RESULTS AND DISCUSSION

Properties of the RFPE

The results from the sample analysis showed that the greatest amount of nutrients was available in fresh serum collected from the coagulation tank while in the further steps of crepe rubber processing, greater contents of nutrients were detected in initial 2-3 steps of processing than the latter steps (For example: the nutrient properties of effluent collected from Dartonfield estate- Table 3). Average Total N, Total K were high in the fresh serum than Total Mg. However, Phosphorus nutrient was not in a detectable range and the average pH value is low in the fresh serum collected from different estate factories (data not shown). Fresh serum collected from Dartonfield Estate factory was used for the treatments.

Table 3: Major Nutrient contents and pH in the effluent samples collected from Dartonfield factory

Sample collected stage	Total N (ppm)	Total P	Total K (ppm)	Total Mg (ppm)	pH
Coagulation tank	560	Not in detectable range	468	118	5.06
Process Step 1	292		250	59	5.45
Process Step 2	327		127	56	6.48
Process Step 3	222		117	92	6.82
Process Step 4	187		91	52	6.04
Process Step 5	163		69	32	6.76
Process Step 6	140		75	26	6.09

The average metal ion contents that were available in the effluent discharged in different processing steps is shown in Table 4. Led content was not beyond the tolerance level for industrial waste discharge according to National Environment Act No. 47 Of 1980. Micro nutrients Zn, Cu, Mn and Fe ion contents were below than the highest tolerable limits to the plants (Smith, 2000).

Table 4: Metal ion content of the effluent in the fresh serum, in the middle stage and end stages of the processing

Metal ion	Different stages of processing	Average Content (ppm)
Zinc	Fresh serum	0.413
	Middle stage	0.333
	End stage	0.096
Iron	Fresh serum	0.624
	Middle stage	0.681
	End stage	0.351
Manganese	Fresh serum	0.057
	Middle stage	0.041
	End stage	0.010
Copper	Fresh serum	0.549
	Middle stage	0.149
	End stage	0.001
Led	Fresh serum	0.646
	Middle stage	0.626
	End stage	0.292

The metal ions including heavy metals in the wastewater that was collected from the discharge unit of the rubber processing sewage system were analyzed by Asia and Akporhonor (2007), reported that the value of Fe, Mn, Cu, Zn, Ni, Cr, V and Pb were 1.85, 0.42, 0.003, 0.02, 0.002, 0.001, 0.021, 0.211 mg/l respectively which were within Federal Environmental Protection Agency Guidelines and Standards for Industrial Waste Management in Nigeria standard for industrial wastewater. A recent study with capsicum plants grown in rubber sludge incorporated medium showed that the levels heavy metals available in the plant matter were lower than the standard acceptable limits (Godagama *et al.,* 2023).

Growth and yield performances in salad cucumber (Cucumis sativus L.) plants in different treatments

According to the statistical analysis there were no significant differences in the rate of growth *i.e* increment of plant height as well as the number of leaves among the treatments including the controls (Table 5). It can be suggested that application of serum combined with reduced Albert fertilizer has not harmfully affected the plant growth indicating the possibility of applying the fresh serum collected from coagulation tank (pH adjusted and trapped for 24 hours) as a nutrient source for salad cucumber plant during its fruiting stage.

There were significant differences observed in crop yield. Treatments with combine use of Albert solution and fresh serum (T2, T3 and T4) and fresh serum alone treatment (T5) gave significantly higher value of crop yield compared to positive control treatment (only Albert fertilizer application) during the experiment period (Table 5). The presence of micro nutrients in the fresh serum might have also affected positively on the growth and yield performances of the crop. Similar results could be observed in a previous study where field application of rubber factory effluent has shown positive impacts on growth and yield characteristics of Cucumber (Eifedivi *et al.*, 2012).

Table 5: Growth rate (plant height, number of leaves) and crop yield of Salad Cucumber Plants

Treatment	Mean rate of the increment of plant height (cm)/month	Mean rate of the increment of number of leaves/month	Mean yield (g)/ plant/month
T1	19.6 ^{A}	3.1 ^{A}	186.25 ^{B}
T2	23.1 ^{A}	3.4 ^{A}	599.1 ^{A}
T3	19.0 ^{A}	3.0 ^{A}	590.1 ^{A}
T4	20.5 ^{A}	3.1 ^{A}	640.9 ^{A}
T5	28.9 ^{A}	3.6 ^{A}	497.8 ^{A}

Mean values followed by same superscript letters are not significantly different at $P < 0.05$.

Greater crop yield in fresh serum combined treatments could be attributed to greater availability of Potassium in the effluent. Although P nutrient was not available in the fresh serum, the P supplied by the fertilizer during the growth stage (during the first month before effluent supplement started), seemed adequate for the extended growth of the salad cucumber crops supplied with Effluent treatment and in further studies it would be better to provide P nutrition with the effluent treatments. Experiment duration was limited to two months since this was a preliminary study with a short-term crop. Although extra supplements such as Potassium sources are commercially used in the industry when salad cucumber is grown under greenhouse condition, such supplements were not used in the experiment for better understanding of the treatment effect alone.

RECOMMENDATIONS AND CONCLUSION/S

Effluent properties showed that fresh serum collected from coagulation tank has a nutrient value to be used regularly as a fertilizer supplement, if it is utilized after neutralization of pH. There was no significant effect of the treatments on plant height and number of leaves after a month of treatment application indicating that the effectiveness of nutrient supplement with fresh serum by cutting down albert solution in the fruiting stage of salad cucumber (*Cucumis sativus L.*). Higher yield could be obtained by combine use of Albert solution and fresh serum compared to the plants treated with only fresh serum or only Albert solution. There is a potential to cut down inorganic fertilizer usage and their cost by substituting freely available fresh serum as a nutrient supplement particularly which contains N, K, Mg, and micro nutrients. This would help in reducing environmental pollution too. Since the coagulation treatments do not include with chemicals consisting with heavy metals, they were not analyzed during the study except Led (Pb). However, in future, it is expected to analyze for heavy metal contamination in the effluent. This study opened a path for further studies using fresh serum as a nutrient source for different growing stages of different crops under different growing media.

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DEVELOPMENT OF CHEMICAL MANAGEMENT STRATEGIES FOR THE BROWN ROOT DISEASE OF RUBBER IN SRI LANKA

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ABSTRACT

Brown root disease caused by the fungus Phellinus noxius is becoming an increasingly important disease condition in Sri Lankan rubber (Hevea brasiliensis Mull. Arg.) plantations, especially in certain agro-ecological regions of the country. However, management strategies over the disease have not been developed, as the disease was not of economic importance till recent years. In the present study, the development of chemical management strategies over the disease was attempted. Screening of potential fungicides was carried out under three phases: in vitro, pot and field experiments. For the assessment of the fungicides under in vitro and polybag conditions, the most pathogenic isolate among the P. noxius isolate collection was used. The in vitro study was carried out using the poisoned food technique and the soil fungicide screening test. Three potential fungicides: Tebuconazole, Hexaconazole and Propiconazole were screened each at five concentrations and with four replicates. The analysis of variance was carried out, and subsequently, mean separation was done with Duncan's Multiple Range Test. Among the treatments, the highest efficacy was shown by Tebuconazole with a total inhibition of the fungal growth at 2 ppm. The pot experiment was carried out for two systemic fungicides at two concentrations. The fungicides were selected based on the results of the in vitro study, the seedlings were inoculated with P. noxius and the respective fungicide treatments were carried out while a disease rank was assigned to each seedling. In the pot and the field trials, the disease level recorded as ranks were subjected to the General Linear Model analysis In the pot experiment, the treatment with Tebuconazole at a concentration of 0.625 g resulted in a significantly lower mean disease rank at both foliar and root symptom studies. In the field-level experiment, the initial infection level was assessed and a rank was assigned for each tree based on the level of foliar symptoms before applying the fungicides and a repetitive application was carried out three months after the first application. After two months of the second fungicide application, the disease infection level of each tree was assessed, and a rank was assigned for each tree. Under the field conditions, Tebuconazole at 1.25 g of a.i./plant concentration was the most effective for immature rubber. It can be concluded that Tebuconazole, could be effectively used as potential means towards the management of the brown root disease of rubber in Sri Lanka.

Keywords: Brown root disease, Fungicides Hevea brasiliensis, Management strategies, Phellinus noxious

INTRODUCTION

Phellinus noxius (Corner) G. Cunn. (Hymenochaetaceae) is a fungus that causes brown root disease in a variety of tree species. It is widely distributed in tropical and sub-tropical regions in Asia (including Southern Japan, Mainland China, Hong Kong, Taiwan and Malaysia), Central America, Africa and Oceania (Larsen *et al.,* 1990; CABI/EPPO, 1997; Chang and Yang, 1998; Ann *et al.,* 2002). The disease has been reported worldwide in a total number of 427 host plants (310 species, 06 sub-species, 42 varieties and 69 forms) (Ranadive *et al.,* 2012) while the hosts include Gymnospermae and both classes of Angiospermae. The cross-inoculation studies have shown a lack of host specificity for various isolates of *P. noxius*, although varying degrees of resistance are seen in different hosts *(Bartz, 2007).* Most of the economically important plantation and other crop species including *Camellia sinensis* (tea), *Coffea* spp. (coffee), *Artocarpus altilis* (breadfruit), *Cinnamomum* spp. (cinnamon), *Theobroma cacao* (cocoa), *Cocos nucifera* (coconut), *Garcinia mangostina* (mangosteen), *Citrus* spp. (citrus), *Mangifera indica* (mango), *Artocarpus heterophyllus* (jack), *Tectona grandis* (teak) and *Swietenia mahogani* (mahogany) are reported to be affected by this disease (Ranadive *et al.,* 2012).

A varying impact of the disease has been reported on different crop and other species in various parts of the world. In Taiwan, it has been reported that the brown root rot disease is a serious cause of decline and death of tropical fruit trees as well as shade, windbreak, and ornamental trees (Chang and Yang 1998; Ann *et al.,* 2002). Brown root rot caused by *P. noxius* is a serious problem of fruit and forest trees at lower altitudes (<800 m) of central and southern Taiwan (Chang 1995; Ann *et al.*, 2002). Bolland *et al.,* in 1988 reported that *P. noxius* is the most widespread and destructive root pathogen in hoop pine plantations *(Araucaria cunninghamiii Ait.)* in Australia. In America, the reforestation projects have been seriously affected when exotic trees such as *Cordia alliodora* and *Swietenia macrophylla* were introduced into native stands became infected and died while fruit tree orchards and woody landscape plants being susceptible to *P. noxius* (American Samoa Community College, 2001). It has been reported that the economic impact of *P. noxius* is highly variable and losses up to 60% can occur in rubber plantations due to the extremely diverse host range and geographical distribution (Nandris *et al.,* 1987). In Sri Lanka, it is frequently reported from certain parts of the country. The situation has been aggravated with the recent expansion of the rubber plantations to non-traditional areas in intermediate and dry zones of Sri Lanka with an increased frequency of disease occurrence.

It is evident that the management of brown root disease has become a severe problem in crop production, and therefore, efforts have been made to manage brown root rot disease worldwide. Among the agronomic practices tested, flooding the field has been stated as one of the most efficient methods of destroying the residual inoculum (Tsai *et al*., 2008; Chang, 1996), yet it is not a practical way of managing the disease in the fields, especially in the dry and intermediate zones of the country, where the disease is most prevalent.

Though overseas reports are present in chemical controlling measures, most of the active ingredients tested are with high toxicity and therefore have been banned from being used in Sri Lanka. Under this background, it is vital to investigate sustainable management strategies applicable under Sri Lankan conditions.

The objective of the study was to evaluate the efficacy of potential fungicides in brown root disease management under *in vitro*, pot and field levels.

MATERIALS AND METHODS

For the assessment of the fungicides under *in vitro* and polybag conditions, isolate 9 of the pathogen was selected, being the most pathogenic isolate among the *P. noxius* isolate collection. The polybag experiment was carried out at Agalawatta, Sri Lanka (WL1a) (Silva *et al.,* 2020).

Under the *in vitro* study, the poisoned food technique (PFT) described by Schmitz in 1930 and the soil fungicide screening test (SFST) described by Zentmeyer in 1955 were used while, both experiments were carried out in a completely randomized design with four replicates. Three potential fungicides were screened in a series of concentrations.

The pot experiment was carried out in a completely randomized design with 20 replicate seedlings and two systemic fungicides were tested in two concentrations. The two fungicides were selected based on the results of the in vitro study, the seedlings were inoculated with *P. noxius* and the respective fungicide treatments were carried out. Thereafter, a disease rank was assigned to each seedling.

The field-level study was designed at five locations. Approximately 12 to 18 trees were used per treatment at each site (the number under one treatment varied according to the number of symptom-showing trees in each location). The initial infection level was assessed and a rank was assigned for each tree based on the level of foliar symptoms before applying the fungicides. After that, the respective treatment was carried out to the trees by pouring the respective fungicides along the trunk after careful loosening of the soil and forming a funnel-like furrow around the base of the tree. A repetitive application was carried out three months after the first application. After two months of the second fungicide application, the disease infection level of each tree was assessed, and a rank was assigned for each tree.

In vitro screening of potential fungicides

Three potential fungicides: Tebuconazole (Folicur, 250 EW, Bayer), Hexaconazole (Hayzole, 50 EC, Hayleys) and Propiconazole (Propiconazole, 50 SL, Hayleys) were screened *in vitro* using two techniques: poisoned food technique (PFT) described by Schmitz in 1930 and soil fungicide screening test (SFST) described by Zentmeyer in 1955. The pathogen was grown on Malt Extract Agar (MEA) at room temperature in 9 cm diameter Petri dishes. A series of concentrations: 0.1 ppm, 1 ppm, 5 ppm, 10 ppm and 25 ppm were used and the percentage of inhibition over control (I) was calculated as follows using the colony diameter as the measured parameter: I = {(C - T) / C} x100 (Vincent, 1927).

Where, I = Percentage inhibition over control
C = Growth of pathogen in control
T = Growth of pathogen in treatment

Screening of potential fungicides under polybag conditions

Based on the effectiveness of the *in vitro* trials, the two systemic fungicides: Tebuconazole and Hexaconazole, were selected to be tested under the polybag conditions. The treatment structure is summarized in (Table 1).

Table 1: Details of the fungicides used in the polybag screening experiment

Treatment No	Name of Fungicide	Rate of application (ml/plant)	Amount of active ingredient/ plant (g)
1	Tebuconazole (Folicur, 250 EW)	2.5 ml	0.625
2	Tebuconazole (Folicur, 250 EW)	5 ml	1.25
3	Hexaconazole (Hayzole, 50 EC)	12.5 ml	0.625
4	Hexaconazole (Hayzole, 50 EC)	25 ml	1.25

Preparation of the artificial inoculation medium

An inoculation medium comprised of rice bran and sawdust (1:2 w/w) with 15% (w/w) moisture was prepared by modifying the method described by Bartz in 2007 The medium was autoclaved for 45 minutes at 121 ºC in polythene bags and was inoculated with the pathogen grown on Malt Extract Agar (MEA). Two agar blocks of 30 cm^2 from the advancing margin of isolate culture was transferred aseptically into each bag and incubated for 12 weeks at room temperature (28 ± 2 ºC) under dark conditions with intermittent mixing. The inoculation was carried out by incorporating 100 g of the inoculated medium into the potting medium as to have contacts with the collar region of each seedling.

Inoculation of the seedlings

Twenty numbers of three-month-old rubber seedlings, each planted in a polybag were artificially inoculated with *P. noxius*-grown in the artificial medium. Two months after the inoculation, the respective fungicide treatment was carried out by pouring fungicides along the main stem after careful loosening of the soil. For each pot, a second application was carried out three months after the first application. Another twenty seedlings were inoculated with the fungus and were kept as controls.

Two months after the second fungicide application, a disease rank was assigned to each seedling according to the ranking system developed by Nandris *et al.,* (1987) with modifications. Based on the level of foliar symptoms, a rank from 0 to 3 was assigned for each plant. The seedlings were uprooted and again a rank was assigned to each seedling based on the disease level of the collar region and the root zone (Table 2).

Table 2: The disease levels of the plants and the rank assigned

Disease levels of the collar region	Disease levels of the foliage	Rank
No infection	No infection.	0
Mycelial crust without root decay	Slight yellowing and/(or) downward curling	1
Mycelial crust with root decay	Yellowing and/ (or) downward curling	2
Plant death	Total wilting of the foliage	3

Field screening of potential fungicides

Based on the results of *in vitro* and pot trials, two fungicides: Tebuconazole and Hexaconazole, were selected to be tested under field conditions. In two preliminary trials: carried out at three clearings at the intermediate zone in Sri Lanka, Tebuconazole (Folicur 250 EW) in 2.5 g of a.i./plant and Hexaconazole (Hayzole 50 EC) in 2.5 g of a.i./plant and 5g of a.i./plant concentrations were used as treatments. As none of the trees under these three treatments did exhibit any brown root disease symptom after one round of fungicide application, lower concentrations were tested at five new locations. The treatments used were Tebuconazole (Folicur 250 EW), in 0.625 g of a.i./plant concentration, and in 1.25 g of a.i./plant concentration, Hexaconazole (Hayzole 50 EC) in 0.625 g of a.i./plant concentration and in 1.25 g of a.i./plant concentration. To each tree, respective fungicide was applied after diluting in water to a volume of one liter. Three trials were carried out in four, five, and six-year-old clearings at Galagedara, Sri Lanka (IL1a), while the other two were in five and six-year-old clearings at Badalkumbura (IM2b). Approximately 12 to 18 trees were used per treatment at each site (the number under one treatment varied according to the number of symptom-showing trees in each location). The initial infection level was assessed by assigning a rank from 0 to 3 for each tree based on the level of foliar symptoms (same given for the polybag experiment) before applying the fungicides. Then, the respective treatment was carried out to the trees by pouring the respective fungicides along the trunk after careful loosening of the soil and forming a funnel-like furrow around the base of the tree. The second application was carried out three months after the first application. After two months of the second fungicide application, the disease infection level of each tree was assessed, and a rank was assigned for each tree.

Statistical analysis was carried out using the statistical software SAS ver. 9.2. While *in vitro* screening of the fungicides, the analysis of variance of the diameter reduction values over the control at different concentrations of the three fungicide (at the SFST trial) was carried out and subsequently, mean separation was done with Duncan's Multiple Range Test (DMRT). In the pot and the field trials carried out for screening of the fungicides, the disease level recorded as ranks were subjected to the General Linear Model analysis in order to find out the variability among the different chemical treatments (as the sample size was large enough).

RESULTS AND DISCUSSION

In vitro screening of potential fungicides

Poisoned Food Technique (PFT)

With all three fungicides, none of the fungal isolates could grow at any of the tested concentrations: 0.1ppm, 1 ppm, 5 ppm, 10 ppm and 25 ppm. Moreover, in all the treatments, the pathogen was unable to resume its growth when the inoculum disk was placed on a fresh growth medium-containing Petri plate indicating that they have been completely killed.

Soil Fungicide Screening Test (SFST)

The three fungicides showed a significant reduction in the growth reduction of the fungus at the four fungicide concentrations (Table 3).

Table 3: Effect of fungicide type and concentration on *P. noxius* growth *in vitro*

Fungicide	The percentage of inhibition of the fungus over the control (cm) at different concentrations of the fungicide (ppm)*			
	0.1	0.5	1	2
Tebuconazole	33.16[a]	55.71[a]	77.66[a]	100.00[a]
Hexaconazole	22.34[b]	44.42[b]	66.97[b]	89.04[b]
Propiconazole	0.00[c]	2.34[c]	13.32[c]	33.60[c]

*Values in the same column followed by the same letters are not significantly different at DMRT at P=0.05

Significantly high inhibition ($P<0.05$) was given by Tebuconazole followed by Propiconazole. Tebuconazole showed complete inhibition of the fungus at the concentration of 2 ppm.

Screening of potential fungicides under poly bag conditions

According to the mean disease ranks of both foliar and root symptoms, Tebuconazole showed significantly lower mean disease rank over Hexaconazole ($P= 0.001$) (Table 4).

Table 4: Effect of fungicide on mean disease rank in the pot experiment

Fungicide	Mean disease rank	
	Foliar	**Root**
Tebuconazole	0.07500[a]	0.12500[a]
Hexaconazole	2.10000[b]	2.25000[b]

*Values in the same column followed by the same letters are not significantly different by DMRT at P=0.001

However, the effect of two concentrations of the fungicides: 0.625 g of a.i./plant and 1.25 g of a.i./plant showed similar effectiveness (P>0.001). Tebuconazole at the concentration of 1.25 g of a.i./plant resulted in total inhibition of disease. Moreover, a significant interaction effect was not observed between the fungicide and the concentration.

Field screening of potential fungicides

Both concentrations of the two fungicides: 0.625g of a.i./plant and 1.25g of a.i./plant, showed a significant variation in the effectiveness with an interaction effect. At both concentrations, Tebuconazole recorded highest efficacy with mean disease ranks of 0.46667 and 0.06494 at 0.625 g of a.i./plant and 1.25 g of a.i./plant, respectively (Table 5), Both fungicides have shown significantly lower mean disease ranks at the concentration of 1.25 g of a.i./plant.

Table 5: Effectiveness of the fungicides measured as mean disease ranks

Fungicide	Mean disease rank at different concentration levels	
	0.625 g of a.i./plant	**1.25 g of a.i./plant**
Tebuconazole	0.46667[a]	0.06494[a]
Hexaconazole	2.18667[b]	1.35065[b]

*Values in the same column followed by the same letters are not significantly different

For the management of brown root disease, different approaches have been used worldwide, which can be broadly classified as the application of inorganic agents, biological agents and adopting healthy agronomic practices.

Lim *et al*., (1990) have tested the volatility and persistence of four fungicides against three basidiomycetous root pathogens, including *Phellinus noxius* and concluded tridemorph as the chemical with the highest efficacy to control the fungi. Out of 46 chemicals tested against *Phellinus noxius* under artificial inoculation and *in vitro* screening, six chemicals: propiconozole, triadimefon, prochloraz, mepronil, bordeaux mixture and phosphonic acid have shown efficacy (Tsai, 2005). In that study, Propiconazole EC was most effective, completely inhibiting the mycelial growth at the active ingredient dosage of 10 ppm. Results of pot experiments also showed the same agents to be effective in decreasing seedling decline of sweet apple (*Annona squamosa*) and loquat (*Eriobotrya japonica*) artificially inoculated with *P. noxius*. In the study by Sun *et al.,* (2020), when a fungicide cocktail was injected into infected tree trunk through shallow holes, the trees recovered from the brown root disease. The chemical mixture contained difenoconazole or propinaconazole (as the fungicide), an insecticide, an antibiotic, a nutrient and a surfactant to treat the already infected plants. In a greenhouse experiment, out of 45 fungicides tested, systemic fungicides triadimefon, prochloraz, and mepronil were found to be non-phytotoxic and strongly inhibitory to the growth of *P. noxius* (Ann and Ko, 1994).

However, some of the the fungicides, which have been previously identified to be effective against *P. noxius* are among the chemicals not allowed in Sri Lanka. Thus, the broad-spectrum systematic fungicides: Tebuconazole, Hexaconazole and Propiconazole in the triazole group which are slight to moderate in toxicity and are used for the control of many fungal diseases in the country in a diverse array of crops, were selected to be tested against *P. noxius.* In the field experiments, too, Tebuconazole at the concentration of 1.25 g of a.i./plant showed significantly higher effectiveness against the disease than two other fungicides at different concentrations, indicating that there would be a possibility of recommending it for the immature rubber plantations. However, the concentration of Tebuconazole has to be validated for the mature plantations with aged trees.

RECOMMENDATIONS AND CONCLUSION/S

With the findings of the current study, it can be concluded that Tebuconazole at the concentration of 1.25 g of a.i./plant could be used to manage brown root disease in immature rubber plantations.

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Technical Session II

“Current Challenges and Climate Resilience in Sustainable Plantation Management”

Lead Presentation Delivered by;

Dr. (Mrs.) Bharti Birla

Chief Technical Advisor

ILO DWT for South Asia & CO for India

EFFECT OF THE SHADE NETS ON GROWTH AND YIELD OF BETEL

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ABSTRACT

Betel (Piper betle) is a perennial climber grown in Sri Lanka. Its leaves are traditionally used for chewing. Sri Lanka earned Rs mil 3077 in 2021 by exporting betel. Pakistan buys almost 99% of betel exported from Sri Lanka. Betel gives farmers a lucrative income and remains a popular cash crop among Sri Lankan farmers. The production of betel for the export market is mainly concentrated in the Kurunegala and Gampaha districts. Leaves with certain quality is bought for export at a higher price. The quality of the betel leaf gets better as it becomes larger, darker-coloured and more pungent. These leaf morphological characteristics can be influenced by altering environmental conditions, especially by shading. However, the best shade net type for optimum yield and quality of betel has not been researched in Sri Lanka. Therefore, this research was conducted at Intercropping and Betel Research Station, Sri Lanka, with treatments; T1 – no shade, T2 –40% shade net, T3 – 50% shade net, and T4 –60% shade net, to find the best type of shade net. The research field was planted in a coconut field to a single-stake system. According to the data, plants under shade nets have higher internodal length, and grow taller, but have few side branches. Further, the shade promoted the quality of leaves suitable for the export market. As these large, dark colour leaves get higher prices, farmers get higher income. However, higher shade, especially over 50% shade net, can reduce the number of leaves produced. Finally, shade nets of 40% to 50% can be recommended for betel cultivation under coconut in the intermediate zone. It helps to increase farmer income when the price for large and dark colour betel leaves is substantially higher than the rest of the leaves.

Keywords: Betel, Leaf, Quality, Shade net, Yield

INTRODUCTION

Betel (*Piper betle*) is a perennial climber of the family *Piperaceae*. Betel leaves are used for chewing with areca nut, tobacco and slaked lime. In addition, it is an essential item for indigenous medicine and traditional ceremonies. Despite the health concerns pointed out by medical practitioners, betel chewing is very common in many Asian countries including Sri Lanka. Therefore, the production and marketing network is well-established all over the Sri Lanka. Conversely, betel production for the export market is mainly concentrated in Kurunegala and Gampaha districts. Betel export from Sri Lanka to Pakistan is a virtual monopsony, which earned Rs million 3077 in 2021 according to the

Annual Report of the Department of Export Agriculture (DEA). Since the demand in local and export markets remains consistent, betel gives farmers a stable income. Therefore, it remains one of the cash crops popular among small-scale farmers in Sri Lanka.

Betel is cultivated by several thousand farmers in Sri Lanka. They have been screening betel cultivars for centuries. Currently, the most common cultivars are "*Maneru" (Maha Maneru)* and "*Ratadalu*" which produce comparatively bigger leaves. Further, field practices in betel vary with farmer experience and locale. However, there are two basic methods of cultivation; 01) bed system and 02) single stake or single support (*Kovul*) system. As the name implies, the bed system indicates planting betel in close spacing (30×45 cm) on a bed, whereas a single stake means planting several betel plants onto a live or dead support at wider spacing (180×180 cm). The Intercropping and Betel Research Station (IBRS) has concluded the yield under both systems is essentially similar. Betel shows dimorphic branching. The orthotropic branches that grow vertically have adventitious roots used for attaching to the support, which horizontally growing plagiotropic branches lack. Moreover, the leaf originating from these branches have a difference in appearance which distinguish them at the market for different prices. Leaves from orthotropic branches called "*Kada Kola*" (*Kada* leaves) fetch higher prices compared to leaves from plagiotropic branches named "*Pidunu Kola*". As betel plants are maintained at harvestable height, the production of "*Kada*" leaves is limited. Thus, farmer income mostly depends on the production of "*Pidunu*" leaves.

In contrast to the local market, Pakistani buyers demand large, dark green-coloured, pungent leaves that identify as "*Kalu Bulath*". This quality of the betel leaf is a determinant of its price. These leaf morphological characteristics are influenced by management practices and environmental conditions, in particular, the light intensity (DEA, 2016a).
Many research outcomes indicate the influence of light on leaf properties (Saha, *et al.,* 2014) (Liphan and Detpiratmongkol 2017). However, an excess shade can lead to a reduction in photosynthetic capacity, growth and yield. Hence the optimum shade level should bring the balance between leaf production and leaf quality. About 45% of shade is recommended by the Department of Export Agriculture to optimize the production of export-quality betel leaf production. However, Malshe, *et al.,* (2015) from India have reported a significantly high survival percentage, vine height and 70.05 per cent increase in leaf yield in betel under 50% shade net compared to no shade.

Also, betel farmers tend to increase the fertilizer and irrigation levels in an effort to obtain maximum production of large leaves. It leads to environmental problems such as nutrient leaching, groundwater contamination, and soil degradation. Shading on other hand does not cause any harmful effects, nonetheless, it could minimize the tendency for fertilizer overuse through improved production of quality leaves. Thus, shading can be useful in sustainable betel production.
Among different methods like intercropping, support trees and shade nets used to obtain a favourable shade, shade nets are widely recognized for their easy maintenance and

stable even shade. However, the best shade net type for optimum yield and quality has not been researched in Sri Lanka yet. Therefore, this research was conducted to find the best shade net for producing export-quality betel leaves under coconut.

MATERIALS AND METHODS

This research was conducted from March 2016 to December 2018 at Intercropping and Betel Research Station, of the Department of Export Agriculture, Sri Lanka. The station belongs to IL1a agroecological zone. A coconut field over 40 years old was selected. The research was laid out in a randomized complete block design with 8 stakes per plot. Betel was planted to a single-stake system. All agronomic practices were carried out as per the recommendations of the DEA. Treatments applied here were; T1 – no shade (Control), T2 – 40% shade net, T3 – 50% shade net, and T4 – 60% shade net. Growth data were collected every other week and yield was collected every third week. Data were analysed using SAS 9.0 package. leaf quality determination and leaf grading were done by experienced officers depending mainly on the leaf size and colour.

RESULTS AND DISCUSSION

Table 1 below shows the growth of betel plants under different shade conditions and respective micro-environmental conditions. As expected, shading has a notable effect on the environmental conditions of the betel field. Also, shading has a significant effect on betel growth.

Table 1: Betel vine growth and micro-environmental conditions under different shade levels

Treatment	Canopy temperature (°C)	Relative humidity (%)	Light (Klux)	Vine length (cm)	No of plagiotropic branch	Internodal length (cm)
T1	34.0 ^{a}	51.2 ^{a}	100.0 ^{a}	107.2 ^{b}	4.8 ^{a}	8.2 ^{b}
T2 (40%)	29.6 ^{b}	48.8 ^{a}	25.9 ^{b}	138.1 ^{a}	3.5 ^{a}	12.3 ^{a}
T3 (50%)	28.9 ^{b}	47.3 ^{ab}	20.0 ^{c}	137.7 ^{a}	1.1 ^{b}	11.8 ^{a}
T4 (60%)	30.6 ^{b}	46.25 ^{b}	18.0 ^{c}	135.3 ^{a}	1.3 ^{b}	11.1 ^{a}
CV	3.29	3.31	13.60	18.55	78.56	13.22

Values in a column with same superscript letters are not significantly different (P<0.05)

Shade nets have significantly reduced the canopy temperature from 34.0 °C in control to 28.9 °C in T3 (Fig. 1). However, an unusual but insignificant increase in canopy temperature has been recorded in T4 compared to T2 and T3. The reduced temperature range in shaded plants is beneficial for plant growth compared to the temperature without shade (control) as described by Kumar (1999).

The relative humidity shows a gradual reduction with increasing shade, making T3 and T4 significantly lower than T1 and T2. The humidity around the plant is directly associated with temperature and evapotranspiration in the field. Hence, reduced canopy temperatures may have reduced the evapotranspiration decreasing the humidity around the plant.

Among these micro-environmental conditions, light exhibits the highest reduction. The 40% shade net (T2) has nearly quartered the light intensity which further reduces significantly under 50 and 60% light conditions. It should be noted that these shade nets provided a shade higher than the percentage (40%, 50%, and 60%) referred to it.

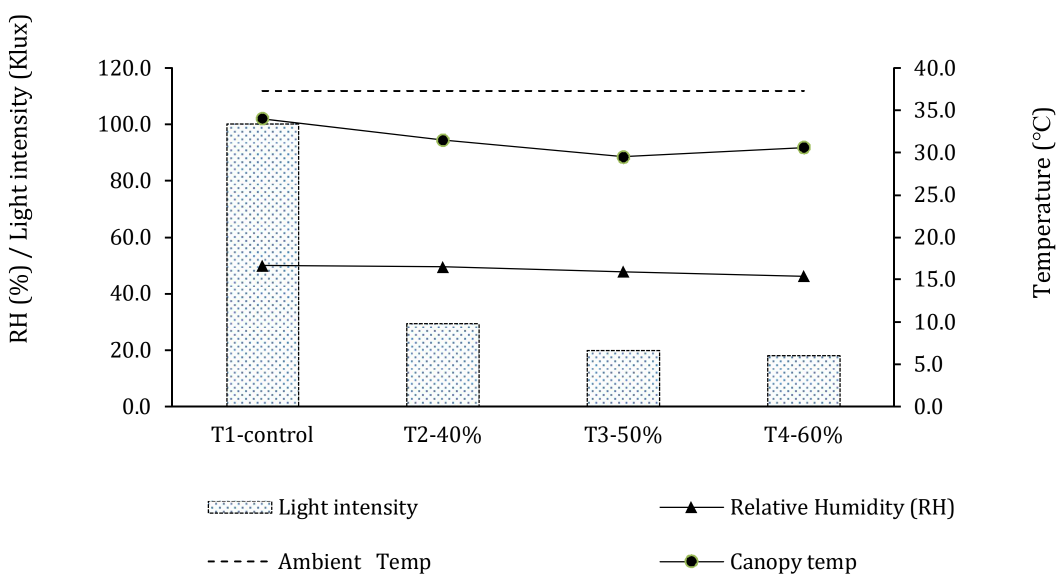

Figure 1: Micro-environmental conditions in betel fields (Temp, Temperature)

Reduction in sunlight has a significant effect on betel growth. Especially it has caused an increase in vine length which is directly related to the increased internodal length under shade nets (Fig. 2). These data demonstrate the photomorphogenesis under restricted conditions of sunlight. The same observation has been made by Malshe, *et al.,* (2015) in India.

Farmers maintain betel plants at harvestable height. Thus, the growth of vertical (orthotropic) branches is limited. Consequently, it produces more leaves on plagiotropic (side) branches which arise from nodes of vertical branches. The longer the internodal length the fewer the number of nodes. Hence, rapid stem elongation due to higher internodal length is not desirable in betel cultivation.

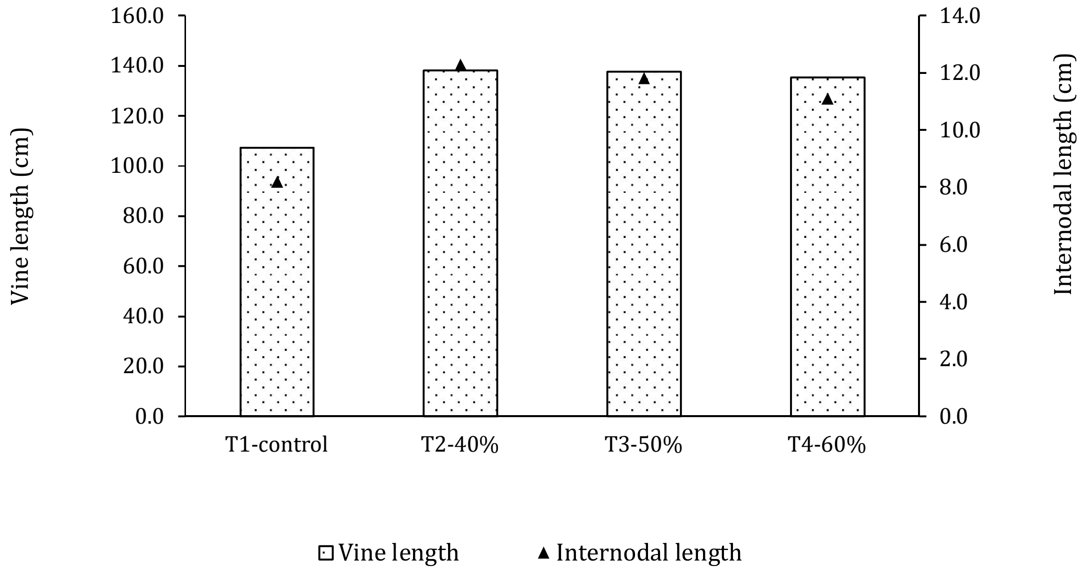

Figure 2: Vine length and Internodal length of betel vine at 6 months after planting under different shade levels

Still, more branches at shorter intervals reduce the space between plagiotropic branches. This dense positioning of branches would result in mutual shading and demote leaf enlargement producing a smaller number of export-quality leaves. Thus, the yield data reveals an equilibrium between the number of leaves and the size of the leaf as influenced by the amount of light received.

Plants under shade need to spread wider with longer branches to harvest more sunlight. Hence, plants in shade are expected to have more branches. Conversely, in this experiment, betel plants under a high shade produced a minimum number of plagiotropic branches. The negative effect of shade on branching had been mentioned in the DEA technical bulletin too (DEA 2016b). According to Table 1, side branch generation in the 40% shade net (T2) remains equivalent to the unshaded condition (T1) while further increase significantly reduces the number of plagiotropic branches per plant (50%, 1.1 and 60%, 1.3).

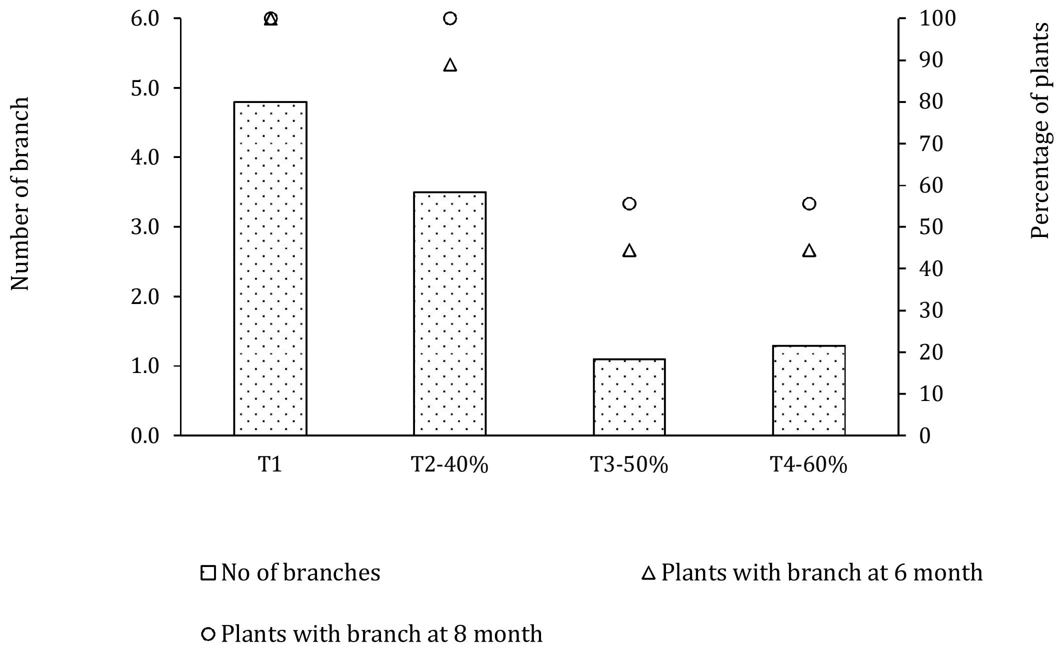

Figure 3: Plagiotropic branches six and eight months after planting

However, a large reduction can be noted in the number of plagiotropic branches in T3 and T4 plants. Some plants were taking a longer time than 8 months to produce side branches as shown in Fig. 3 above. It is clear that the dry matter allocation of betel plants under limited light conditions principally diverted to increasing vine height rather than producing more side branches. It might have a positive impact on leaf size but negatively affects the number of leaves.

Table 2: Yield of betel under different shade levels (number of leaves/single stake)

Treatment	Yield 2016-17	Yield 2018	Cumulative yield	Export quality leaf percentage
T1	414.1 [a]	695.8 [a]	1110.0 [a]	61.1 [c]
T2 (40%)	345.4 [a]	692.3 [a]	1037.6 [ab]	69.8 [bc]
T3 (50%)	212.4 [b]	684.1 [a]	896.5 [bc]	72.5 [ab]
T4 (60%)	192.4 [b]	594.7 [a]	787.8 [c]	79.3 [a]
CV	34.29	28.41	23.50	14.17

Values in a column with same superscript letters are not significantly different (P<0.05)

Table 2 above shows the yield of betel under different shade conditions. During the first 18 months (2016-17) there was a significant difference in the number of leaves produced.

Plants receiving low amounts of light have produced a very low number of leaves, probably as a result of limited photosynthetic capacity.

It should be considered that the betel plants are perennial and produce leaves for many years. Therefore, the yield up till another year has been recorded. In contrast to the early growth period, this yield, measured in terms of the number of leaves produced, has no significant difference between treatments. This contradicts Malshe, *et al.,* (2015) who reported an increase in leaf number with shade. However, there is about a 15% reduction under 60% shade net. It implies that shade over 40% can be harmful to betel plants. Still the results suggest that the shade nets up to 60% would pass an adequate amount of light to produce the optimum number of betel leaves in the Intermediate Zone of Sri Lanka. Plants can adapt to shading with morphological changes for maximum use of sunlight and produce as many leaves as in no-shade conditions.

Nevertheless, the shade influences the leaf morphology and alters the leaf quality parameters like colour and size. The increased percentage of export-quality leaves was a convincing finding of this experiment showing the effect of the shade nets i.e., the light intensity, on the quality of betel leaves. As shown in Table 2, the light intensity under shade nets has a negative relationship with betel leaf quality. The higher the shade, the higher the percentage of export-quality leaves. Under 50% and 60% shade nets, betel produces more than 70% leaves at export quality.

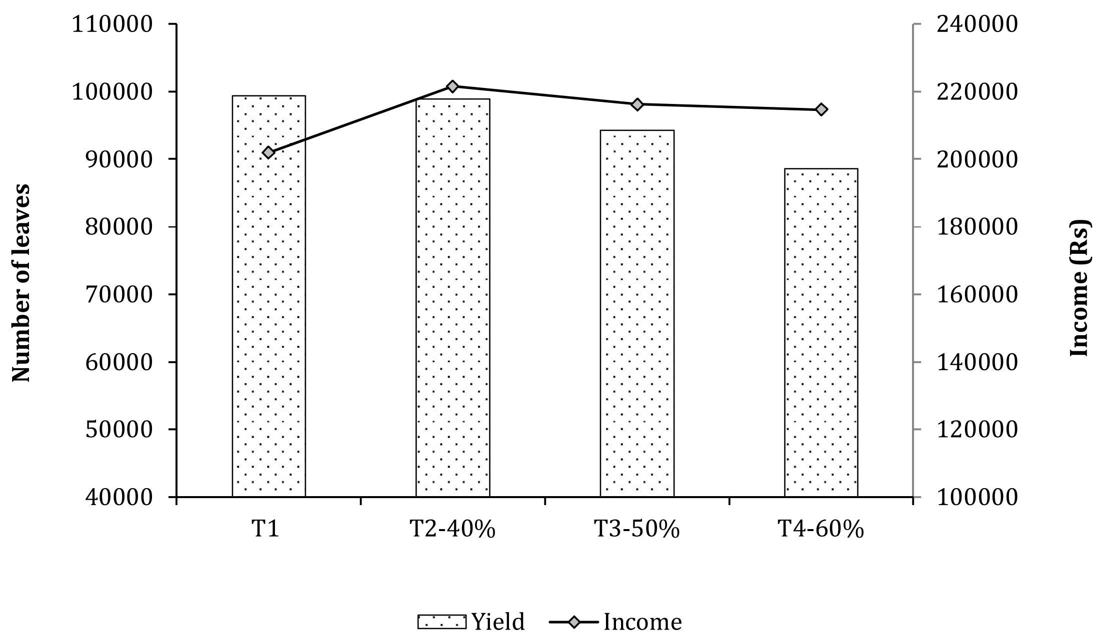

Figure 4: Yield and income per harvest from 1000 betel stakes (~1 ac)

Given the negative effect of shade on the number of leaves and the positive effect on the share of export quality leaves, it is better to compare the income to decide the best treatment from the farmer's perspective. Fig. 4 shows the situation of a betel farmer having 1000 betel stakes. The income has been calculated using the mid-2018 prices taken from the DEA website. During this period, export-quality betel leaf received Rs. 3.00 while the local market quality leaf received only 50 cents. According to the calculation, even though a farmer can obtain the maximum number of leaves under no shade conditions, income will not be maximized. The highest income (Rs 221,971.00) was recorded under 40% shade net (T2) while T3 (50%) and T4 (60%) also recorded a comparable income (T3 = Rs 218,254.00 and T4 = Rs 219,235.00), that is higher than no shade (T1 =Rs 202,063.00).

It should be noted that this calculation depends on the price of betel leaf. Here 2018 prices have been used. Additional income within the first three years alone could justify the investment in shade nets. However, considering the increasing trend of betel leaf price (Fig. 5), it can be determined as a profitable investment. Hence, the use of shade nets can be recommended for the production of export-quality betel leaf.

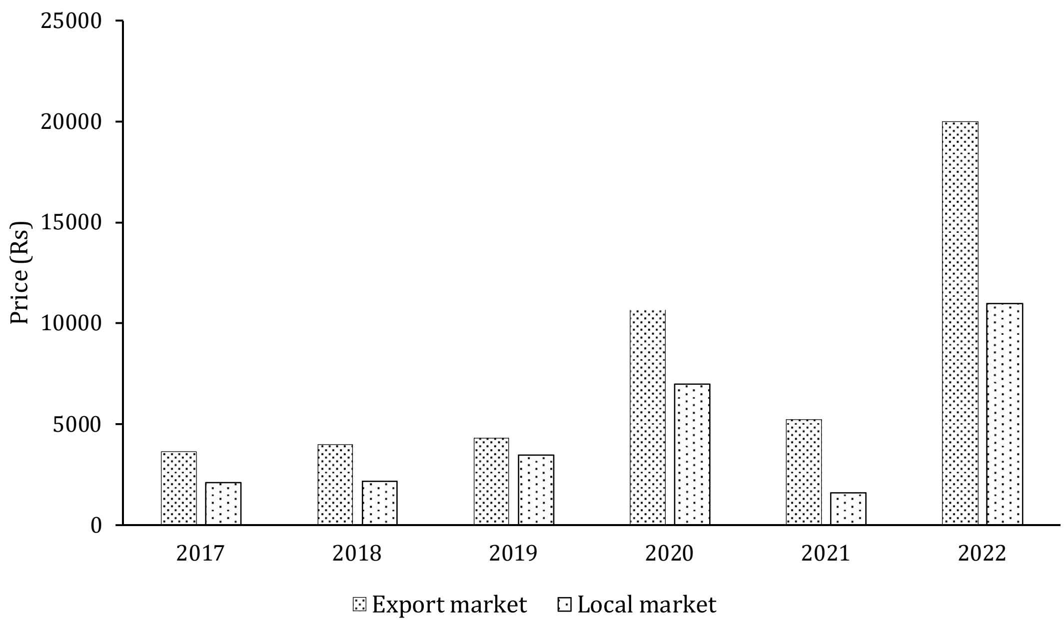

Figure 5: Farmgate price of 1000 betel leaves in February from 2017 to 2022

Limitations

This research has been conducted at Intercropping and Betel Research Station, Narammala. It is situated in the Low-country Intermediate zone of Sri Lanka. Any different agroclimatic zone can vary in response of betel to the use of shade nets. Since the wet zone generally has high cloud cover, lower sunshine hours, low ambient temperatures and high relative humidity, it may be rational to assume more permeable shade nets (<40%) are suitable for the wet zone and vice versa (around 60%) for the dry zone. However, it is necessary to conduct further research for evaluating the impact of shade nets on betel cultivation in different agroclimatic regions.

Betel is cultivated per two systems, viz., bed system and single-stake (single-support/"*Kovul*") system. This research has been conducted for a single-stake system which is drastically different from the bed system. The bed system allows more mutual shading and high relative humidity conditions while the single-stake system improves ventilation within the crop. Hence, it is not advisable to generalize these findings to betel cultivations on the bed system. Further research must be carried out to assess the effect of shade on betel grown on beds.

Here, the farmer income has been calculated using 2018 prices. Different prices or the price difference between export-quality betel leaf and local market betel leaf can change the outcome. However, the large difference between these prices is a fact that most farmers depend on. Further, even in the local market, the larger leaves receive a fairly higher price than the smaller leaves.

RECOMMENDATIONS AND CONCLUSION/S

The beneficial effect of shade nets on betel plant growth and yield is clearly shown in these results. Shade nets make changes in the microenvironment that is beneficial for the leaf quality. Plants under shade nets have higher internodal length and grow taller. Higher internodal length creates more space between side branches. Thus, the shade nets promote the production of large and dark colour leaves that is in demand in the export market. As it receives higher prices in the market, farmers get better income.

However, high shade reduces the number of leaves produced considerably. Even though there is no significant difference between 40% and 60% shade nets, the downward trend is visible. Thus, thicker shade nets, probably over 60%, can be detrimental to betel leaf production.

Shade nets of 40% to 50% shade are best for betel cultivation under coconut in the intermediate zone of Sri Lanka. It enhances betel plant growth and yield. Finally, by using shade nets farmers can increase the percentage of export-quality leaves and their income as well, provided that the price for betel leaf in the export market is substantially higher than local market.

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SEASONAL CHANGES IN YIELD AND RELATED LATEX PHYSIOLOGICAL PARAMETERS IN RUBBER (*Hevea brasiliensis*) TREES APPLIED WITH DIFFERENT TYPES OF ETHEPHON

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ABSTRACT

Wintering of rubber tree is an annual event that generally lies between months of February to May. Various physiological and metabolic processes in the tree are affected with the wintering leading to low productivity in trees. Post- wintering is considered as the time period with an increase in latex yield after the wintering. This paper discussed the effect of water based and oil-based formulations on yield and related latex physiological parameters during low yielding wintering period and high yielding post wintering period. Mature rubber plantation with RRIC 121 genotype tapped on BO-1 under S/2 d4 system with the recommended stimulation protocol had been selected for the study. Trees were applied with water- based ethephon and oil- based ethephon for the yield stimulation. Yield and related latex physiological factors were determined on each tapping day during wintering and post-wintering period. Yield and related latex physiological parameters varied through wintering and post- wintering seasons. Lower sucrose, higher inorganic phosphorus and lower plugging index indicated the higher rubber yield during high yielding post wintering period. Higher levels of thiol during low yielding season revealed lesser reactive oxygen species content due to lower metabolic activity in laticifers. Lower polyphenols causes less discoloration during post- wintering season compared to wintering period. Despite of the time of the year, both ethephon stimulant types had a more or less similar impact on latex yield and latex physiological parameters of rubber trees.

Keywords: *Hevea*, Oil- based ethephon, Post- wintering, Water- based ethephon, Wintering,

INTRODUCTION

Rubber tree (*Hevea brasiliensis*) is one of the major economic plantation crops in Sri Lanka. Rubber trees undergo an annual event of leaf shedding which generally falls between February to April in a year in traditional rubber growing areas. This is also known as wintering period of rubber and causes defoliation of rubber trees followed by re-foliation at the end of wintering (Vinod *et al.*, 1996). This is usually associated with dry climatic conditions (Verheye, 2010). Wintering pattern depends on the type of the *Hevea* clone, age of the plants, location and climatic parameters (Suryakumar *et al.*, 2002). It is well known that wintering of rubber has an impact on metabolism of the rubber tree, production of latex and subsequently latex yield (Chantuma *et al.*, 2017). Previous literature has shown that changes in quebrachitol and reducing sugars could be observed during the wintering period. Furthermore, variations in latex constituents such as protein, potassium and phosphorus contents were found to be related with the wintering followed by re-foliation. Rubber tree uses its organic and mineral reserves for the regrowth of the leaves after the defoliation. Therefore, it has been reported that rubber trees require several weeks after re-foliation in order to recover the latex production (Jacob *et al.*, 1989). Reduction of carbohydrate levels can also be observed after defoliation which indicates the increased utilization of carbohydrates for the metabolic activities of new leaves and flowers (Vinod *et al.*, 1996). Next period after the wintering which is called as post- wintering starts from May and continues to high yielding period which is around August to October (Wijesuriya *et al.*, 1997).

Currently several issues such as shortage of harvesters, fluctuation in rubber price and high cost of production (COP) are making a huge impact on rubber plantation industry (Prasanna *et al.,* 2010; Rodrigo *et al.,* 2011). Low intensity harvesting (LIH) systems together with appropriate ethephon stimulation (Gao *et al*., 2018) have been introduced in order to mitigate these issues and to ensure sustained production in rubber plantations. (Njukeng *et al.,* 2011).

Sucrose, inorganic phosphorus, thiol and polyphenols are concerned as the major physiological parameters of rubber latex. These parameters together with latex flow parameters determine the productivity of rubber trees and the quality of rubber latex (Kudaligama *et al*., 2021).

Ethephon is a kind of plant growth regulator that penetrates into the plant tissues and decomposes to produce ethylene that increases the activities of anabolic physiological processes such as biosynthesis of rubber and related proteins (Tseng *et al.,* 2000; Coupe and Chrestin, 1989). Ethephon induces sucrose hydrolysis in tissues, thus the carbon supply for rubber biosynthesis through increased glycolysis (Tupy, 1985; Mesquita *et al*., 2006). Also, released ethylene inhibits latex coagulation and avoids blockings by making walls of laticiferous vessels rigid and thickened (Shi *et al.,* 2016). Furthermore, effect of ethephon on cell membrane permeability results in decrease of laticiferous vessel obstruction (Zhu and Zhang, 2009). As a result of delaying the plugging of latex vessels, the duration of latex flow is increased (Emuedo *et al*., 2017; Gao *et al*., 2018). Thereby the yield per tapping is increased (Kudaligama *et al.,* 2013).

There are two types of commercial ethephon mixtures (*i.e.* water-based and oil-based) which are available for stimulation of rubber trees in Sri Lanka and both are imported in ready-mixed form.

Considering the lower physiological performance of rubber trees during wintering, application of yield stimulants has been suspended during the wintering season in the stimulation protocol recommended for S/2 d4 system (Rodrigo *et al*., 2011). As the productivity of rubber is comparatively lower in the wintering period than the other time of the year, suspension of stimulant application allows to maintain the trees in a more stable physiological status (Chantuma *et al*., 2017). Though ethephon stimulation was suspended with the onset of wintering, its influence on yield related parameters can be retained for a certain period.

Though the yield performance and physiological changes of low intensity harvesting systems with different ethephon types had been studied previously (Karunarathne *et al*., 2019), their seasonal changes have not been studied under Sri Lankan conditions. Therefore, this study has been conducted with a view to investigate the seasonal changes in yield and related factors affecting latex regeneration and flow of *Hevea brasiliensis* harvested under S/2 d4 with the application of two types of commercially available ethephon.

MATERIALS AND METHODS

Mature rubber field replanted with RRIC 121 *Hevea* genotype and tapped on first virgin panel (BO-1) with S/2 d4 (half spiral, once in four days) tapping system at Galewatte Division of Dartonfield Estate in Kalutara district was selected for the study. Two commercial ethephon mixtures, i.e. water-based and oil-based currently marketed in Sri Lanka were selected as the stimulants. Randomized complete block design (RCBD) with three replicates was followed and three sub-samples had been done for each replicate. For each sub-sample ten trees with equal vigour had been randomly selected. As per the recommendation for S/2 d4 system, each tree was applied with 1.6 g of 2.5% semi- solid ethephon at the end of January and no stimulation has been applied during the wintering period (February to April) (Rodrigo *et al*., 2011). Stimulation was commenced again at the end of April with the same rate and continued monthly (Rodrigo *et al*., 2011). Important yield related factors such as dry rubber content (DRC) of latex (Anon., 1984), daily dry rubber yield per tree (calculated according to the DRC and latex volume of a tree) and latex plugging index (Milford *et al.,* 1969) were determined on each tapping day after stimulation with the two different types of ethephon during wintering (February to April) and favourable (June to August) seasons.

Latex samples were collected to the vessels immersed in ice, avoiding initial five minutes after tapping. Serum was extracted by coagulating 2.5 g of latex in 25 ml of 2.5 % trichloro acetic acid (TCA) and used for testing latex physiological parameters during two seasons.

Determination of sucrose content

Test samples were prepared by diluting 0.1 ml of latex serum with 0.4 ml of TCA. Sucrose content was determined using the anthrone method described by Scott and Melvin

(1953). Absorbance of the samples was measured at 620 nm using a UV-VIS Spectrophotometer (SHIMADZU UV-1800). Sucrose content of the samples were determined using a calibration curve prepared with a range of sucrose concentrations.

Determination of inorganic phosphorus content

Test samples were prepared by diluting 0.4 ml of latex serum with 1.6 ml of TCA. Inorganic phosphorus content was determined using the method described by Taussky and Shorr (1953). Absorbance of the samples was measured at 740 nm using a UV-VIS Spectrophotometer (SHIMADZU UV-1800). Inorganic phosphorus content of the samples was determined using a calibration curve prepared with a range of potassium dihydrogen phosphate concentrations.

Determination of thiol content

Test samples were prepared by diluting 1.0 ml of latex serum with 1.0 ml of TCA. Thiol content was determined using the method described by Boyne & Ellman (1972). Absorbance of the samples was measured at 412 nm using a UV-VIS Spectrophotometer (SHIMADZU UV-1800). The concentration of thiol of the samples was determined using a calibration curve prepared with a range of glutathione (reduced) concentrations.

Determination of polyphenol content

Test samples were prepared by diluting 1.0 ml of latex serum with 1.0 ml of TCA. Modified Folin-Ciocalteu method was used to determine polyphenol contents of the samples (Turkmen *et al*., 2006). Absorbance of the samples was measured at 750 nm using a UV-VIS Spectrophotometer (SHIMADZU UV-1800). The concentration of polyphenols of the samples were determined using a calibration curve prepared with a range of gallic acid concentrations.

Statistical analysis of data

Data were analyzed using SPSS software. Independent samples T- test was done for the variables at the significance level of 0.05. Two T- tests were carried out separately to compare the different yielding seasons and different ethephon types as the independent variables.

RESULTS AND DISCUSSION

A clear variation in latex physiology was observed in trees stimulated with oil- based and water- based ethephon during low yielding wintering and high yielding post wintering seasons (Fig. 1).

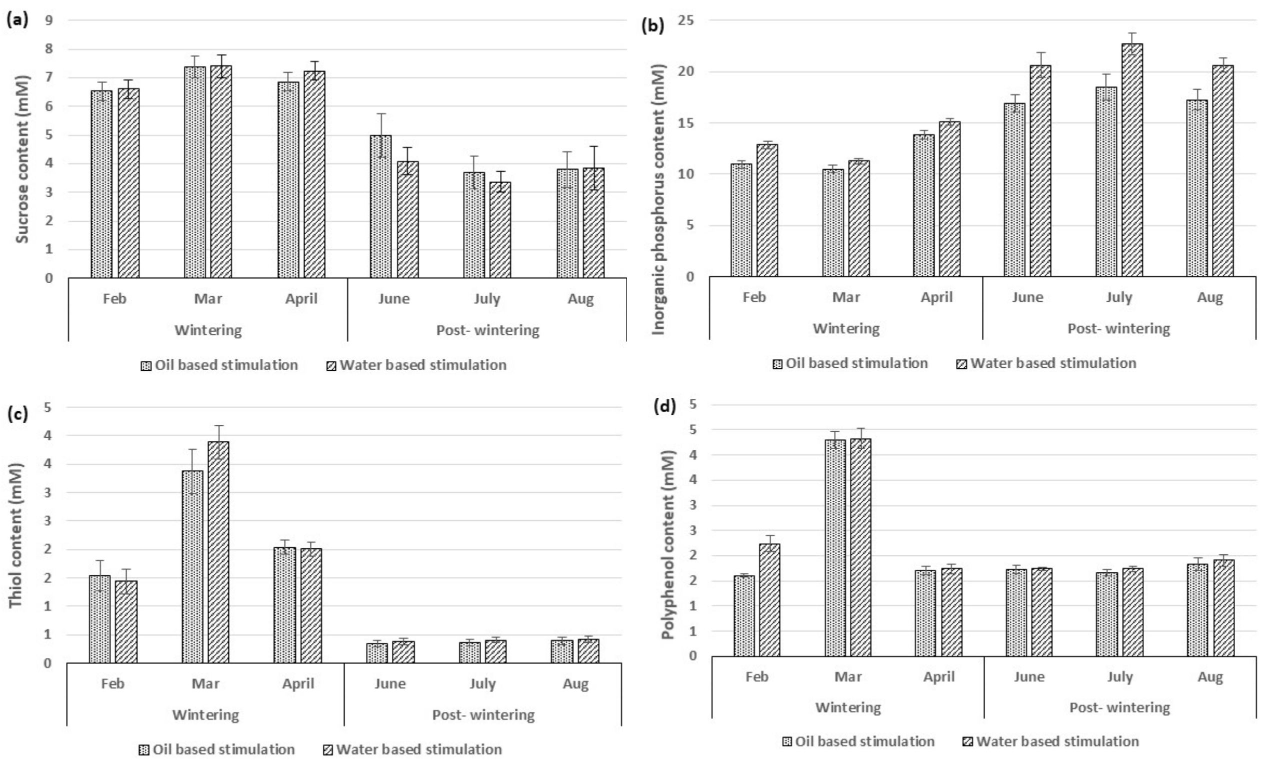

Figure 1: Variation of (a) sucrose, (b) inorganic phosphorus, (c) thiol and (d) polyphenol content of rubber trees stimulated with different types of ethephon during low and high yielding periods.

Sucrose is the main raw material in rubber biosynthesize and metabolized into polyisoprene (rubber) in the laticiferous cells in *Hevea* trees. Sucrose content during the high yielding period was significantly lower than the low yielding wintering season in rubber trees stimulated with both types of ethephon (P=0.000) (Fig. 1a). High sucrose content reflects the lower regeneration of latex which is due to low anabolism of isoprene during the wintering season. It commenced during refoliation and existed until maturity of the canopy at the end of April. During June – August time, photosynthesis elevates and as a result, latex regeneration increases and latex vessels are activated in a higher capacity utilizing the sucrose in the laticifers resulting lower sucrose contents. Sucrose content of oil- based ethephon stimulated rubber trees varied between 6.50 - 7.40 mM during wintering period whilst this variation was between 3.70 – 5.00 mM during the high yielding season. Variation with water based ethephon during wintering was 6.60 – 7.40 mM and it was 3.35 - 4.10 mM during the high yielding season. Pattern of variation in latex sucrose with both type of ethephon was more or less similar during the observed period. Further, no significant difference in average latex sucrose contents was observed between the oil- based and water- based stimulations during the period (p=0.809, p=0.432).

Inorganic phosphorus content of latex is directly correlated with the latex production of trees and it is an indicator of energetic level of metabolism of latex cells (Jacob *et al.*, 1989; Gohet *et al.*, 2008). Despite of the type of ethephon latex inorganic phosphorous level during the low yielding wintering period was lower than in the high yielding post wintering period (P=0.000). Higher metabolic activity and energy consumption in latex regeneration during high yielding months resulted higher inorganic phosphorous content in latex than low yielding wintering months. Water- based stimulation showed a higher increment in inorganic phosphorus content than that of oil- based stimulation in both seasons (Fig. 1b).

Latex thiol content has a direct relationship with latex production. It was reported that thiols act as a potential activator for key enzymes such as invertase and pyruvate kinase (Jacob *et al.*, 1989). Thiol also acts as an antioxidant that protects cells against damages caused by reactive oxygen species (ROS) (De Costa *et al.*, 2006). Generally, thiol content during low yielding period was higher and the highest thiol content in latex was observed during March with both types of ethephon. Comparatively post- wintering high yielding months had a more or less similar thiol content in latex with an average of 0.37 ± 0.32 mM in oil- based stimulation and 0.40 ± 0.30 mM in water- based stimulation (p=0.000). Comparatively low metabolism in laticifers during low yielding period consumes lower thiol content to remove ROS in latex. Subsequently with the increased yield during June – August time latex thiol content had dropped. Variations of thiols in water-based ethephon and oil-based ethephon treatments were more or less similar over the two periods investigated (p=0.987, p=0.464) (Fig. 1c).

Average polyphenol content in latex was significantly higher in wintering period when compared to post- wintering months with both oil- based stimulation and water- based stimulation (p=0.014). Higher polyphenol content in latex may result in latex discoloration in the presence of polyphenol oxidase enzyme (Yapa, 1976). On the other hand, higher phenols might be due to the reduced levels of polyphenol oxidase enzyme which is a key enzyme in coagulation of latex (Coupe and Chrestin, 1989). As for the results, a higher degree of discoloration may result in latex during wintering season than the post- wintering.

The highest polyphenol content had been observed with the refoliation during the March. When the canopy gradually matures towards the high yielding period, latex polyphenol content reduces with both type of ethephon. In addition, no significant difference was observed in polyphenol contents between two types of stimulations throughout the study period (p=0.915, p=0.437).

Seasonal variations in latex yield and flow related parameters of ethephon stimulated rubber trees were observed as shown in Fig. 2.

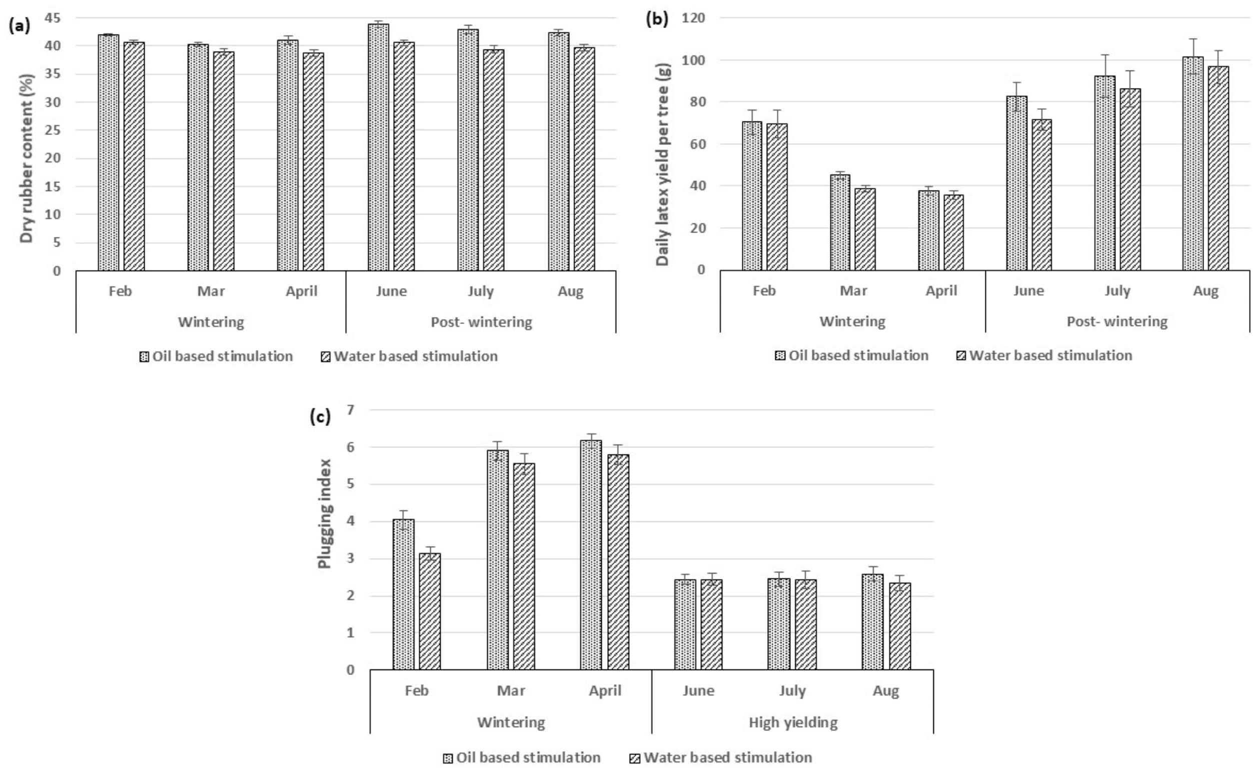

Figure 2: Variation of (a) latex dry rubber content, (b) daily dry rubber yield and (c) plugging index of trees stimulated with different types of ethephon during low and high yielding seasons.

With the beginning of wintering, dry rubber content of latex tends to reduce with both types of stimulants. However, oil based ethephon gave comparatively higher dry rubber content than water based ethephon during wintering (Fig. 2a). Variation of dry rubber content of *Hevea* latex stimulated with water- based ethephon has not been significantly affected during wintering and post- wintering period. However, post- wintering had a significant impact ($p= 0.025$) on increasing of dry rubber content of latex stimulated with oil- based ethephon than the wintering season. Previous studies have also reported higher values in dry rubber content with the oil- based stimulant (Karunarathne *et al*., 2019).

Dry rubber yield per tree per tapping (g/t/t) showed a significant variation between wintering and post- wintering periods for both oil-based ethephon and water-based ethephon treatments ($p= 0.000$). From February to April, daily dry rubber yield from a tree gradually decreased to a minimum value in April. With the maturing of the canopy, an increasing trend has been observed in variation of yield from June to August period (Fig. 2b). The lowest yield has been observed during March-April period and the highest values were observed during August. Average yield resulted during the wintering and post- wintering seasons was 51.06 ± 3.67g and 92.15 ± 4.50g with the oil- based stimulation whereas 48.06 ± 4.24g and 84.93 ± 4.64g with the water- based stimulation respectively. An increase of 41.09g in yield was observed from wintering to post-wintering in oil- based ethephon stimulated rubber trees and it was around 36.87g with water- based ethephon (Fig. 2b). It shows that the reduction in yield due to depletion of carbohydrates with the defoliation along with the re-foliation and recovery of latex regeneration when it comes to post- wintering. Dry rubber yields had a more or less similar variation with two types of ethephon over the wintering (p=0.737) and post-wintering (p=0.296).

Plugging index is related to the reduction of speed of latex flow with time (Coupe and Chrestin, 1989). Generally, plugging index during low yielding wintering season is higher than that during high yielding months and this was one of the main reason for low yield during wintering months. When considering the low yielding months, the lowest plugging index had been observed during February and it has been increased thereafter reaching to the maximum in April. However, in high yielding three months, more or less similar values had been observed which was lower than the values observed during low yielding months. According to the results, higher plugging index was observed with oil- based stimulation during wintering period with a statistical significant difference of 0.049. Plugging index values of water-based ethephon stimulated rubber trees also showed a statistical difference between wintering and post- wintering seasons (p= 0.046) (Fig. 2c). Further, plugging index did not vary between two types of ethephon throughout the study period. (p=0.638, p=0.189).

Considering about the Intake per Harvester (IPH), it varied between 11.30 kg and 21.14kg during the wintering months and 24.80kg and 30.50kg during post- wintering period with the oil- based stimulation. However, with water- based ethephon stimulation, this variation was 10.70 - 20.90 kg during the wintering period and 21.50 - 29.07 kg during high yielding period. Post- wintering period resulted in an average IPH value approximately high as two times as the average value of the wintering months.

RECOMMENDATIONS AND CONCLUSION/S

Yield related latex physiological parameters of rubber trees showed some variations between the wintering and post- wintering seasons. No adverse effects were observed for the type of stimulant on the yield and related latex physiological parameters in two seasons. Lower sucrose and thiol contents, together with a higher inorganic phosphorous content in latex reflect a higher yielding capacity in trees during the high yielding post wintering season and vice versa during the low yielding wintering period. This has been clearly shown by the yield resulting from the trees during the two yielding regimes. However, the results indicated that the actions of both ethephon types on yield and related latex physiological parameters of rubber trees were more or less similar during both wintering and post- wintering period. Increased latex polyphenols content during wintering makes rubber latex more prone to discoloration than post- wintering period. Considering the yield related parameters, increased yield and reduced plugging indicate higher time duration of latex flow and higher yields during the post- wintering than the wintering period.

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PERFORMANCE OF TEA (*Camellia sinensis*) IN DRY AREAS OF SRI LANKA UNDER IRRIGATED CONDITION

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ABSTRACT

Tea cultivation of Sri Lanka is mainly limited to wet zone of Sri Lanka, where high annual rainfalls are available(>2000mm) and temperature does not exceed critical levels (<35^{0}C) at present. However, with the expansion of smallholder farmers, tea has been extended to boundary areas of wet zone agroclimatic zone. Though some previous attempts to cultivate tea in the dry zone have not been successful, due to various, mainly managerial issues, some small holder farmers have started cultivating tea in high temperature areas, once considered to be unsuitable for tea, with micro-irrigation.

This study evaluates the physiological performance of irrigated tea grown in Rambukana, Sri Lanka in dry and wet seasons of 2022. The study area experiences drought stress in January to March and July & August months. On average, leaf temperature of the plants remained above 35^{0}C in both dry & wet seasons. Though leaf transpiration remained unchanged in both seasons, stomatal conductance increased by 113% during the wet season. Photosynthesis rate of the plants increased by 24%. Intrinsic water use of the plants was increased by 30% during the wet season. The study reveals that amidst mostly unfavorable growing conditions, tea can successfully be grown in marginal growing areas with micro-irrigation. However, to capture other advantages of growing tea in such areas with favorable landscape for mechanization, more studies are required to find suitable adaptation of mechanization. Further, micro-irrigation application needs more fine-tuning studies to gain potential maximum outputs.

Keywords: Drought, High temperature, Tea cultivation, Tea physiology, Water use

INTRODUCTION

Tea [*Camellia sinensis* (L.) O. Kuntze] is the main agriculture export crop of Sri Lanka, with nearly 10% of island's total population directly or indirectly related to tea industry. Total export value of tea in 2022 is US $ 1.3 bn (Molligoda 2022). Even with production decline, due to restriction on agriculture inputs, the total earnings from tea achieved US $ 1.17 bn in January to November, 2022 (Anon. 2022). However, tea exporters have shown that the Sri Lanka tea industry has the potential to achieve US $ 5.0 bn export target (Alahapperuma 2013).

Achieving higher export targets could be accomplished through achieving higher export prices for the product or by increasing the production. Measures like crop and agronomic practices improvement can be used to increase the production from existing lands. However, the downward production trend, since 2015/16, shows the limitation for such an approach. Another approach for production increase is the expansion of tea growing areas, with new technologies like micro irrigation. East African countries have achieved higher success in introducing new technologies and expanding tea growing areas (Carr and Stephens 1992). As a major producer, India too is expanding its tea growing areas, encouraging new plantations (Dutta 2021). There were attempts earlier in Sri Lanka as well to test the tea cultivation in Girandurukotte area (System C), under Mahaweli development scheme (Yogaratnam and Dissanayake 1984) (Fig. 1).

Figure 1: Tea and rubber intercropping trial at Mahaweli System C

With the expansion of tea production from large estates to small holders, many small farmers are seeming to be growing tea as a regular cash crop in boundaries of conventional tea growing areas. Some of them adopt micro irrigation, instead of traditional rain-fed cultivation, with the number increasing. While, institutions like Sri Lanka Tea Board (SLTB) and Tea Small Holder Development Authority (TSHDA) assisting the farmers financially for micro-irrigation establishment, there is a gap in cohesive institutional support for tea irrigators as well as in depth studies to solve application related problems and for maximizing the returns on irrigation. This study explores the performance of tea plants, under micro irrigation in the intermediate zone of Sri Lanka, related issues and potential positive impact on the Sri Lankan tea industry and economy.

MATERIALS AND METHODS

A privately owned land, located in Katupitiya, Rambukkana of Kegalle district was selected for the study. The geographical coordinates of the location are Latitude $7^{0}21'$ N and longitude $80^{0}22'$ E and 166 m amsl. The area is on the border of the Low Country Wet zone agroclimatic zone. The land was earlier a monoculture coconut plantation of 2 acres (0.83 ha). The owner has started a tea cultivation, as an intercropping in 2008 with the assistance of Kegalle Regional Office of Tea Smal Holder Development Federation, as a solution for higher cost of weeding in a coconut monoculture. Initially, the farmer has started the planting with installation of a drip irrigation system, with fertigation facility. Subsequently, set of sprinklers too had been established as an irrigation facility. Tea harvesting had been carried out with harvesting machines. However, limitations of fertilizer applications and subsequent yield reduction had compelled to employ manual harvesting.

The physiological processes of photosynthesis, respiration, stomatal conductance and leaf temperature, were analyzed using ADC Bioscientific LC*pro* gas analyzer (ADC Bioscientific 1993, Hunt 2003), during mid-hours of the day. Measurements were taken to collect the data using mature leaves, which were fully exposed to sunlight. Though it was planned to collect monthly physiological measurements, transport limitations due to lack of fuel supply prevented regular measurements in the wet season.

RESULTS AND DISCUSSION

General Climate of the Area

The study area, which belongs to WL2b agro-ecological region, where long term average annual rainfall is >2200 mm and rubber, coconut, mixed home gardens and paddy are the mainly growing crops. The average monthly ambient temperature is 24.5 ± 0.2^{0}C, with the highest average temperature of 31.1^{0}C, recorded in March. During the months of March to May, it recorded an average temperature of above 25.0^{0}C. The lowest ambient temperature of 20.3^{0}C was recorded in January. The area received an average of 7.5 ± 0.2 sunshine hours, with average relative humidity of 82.3 ±1.5% (Fig. 2). These climatic parameters, specially the average temperature and ample sunshine hours can be considered as healthy for a successful tea plantation (Carr and Stephens 1992).

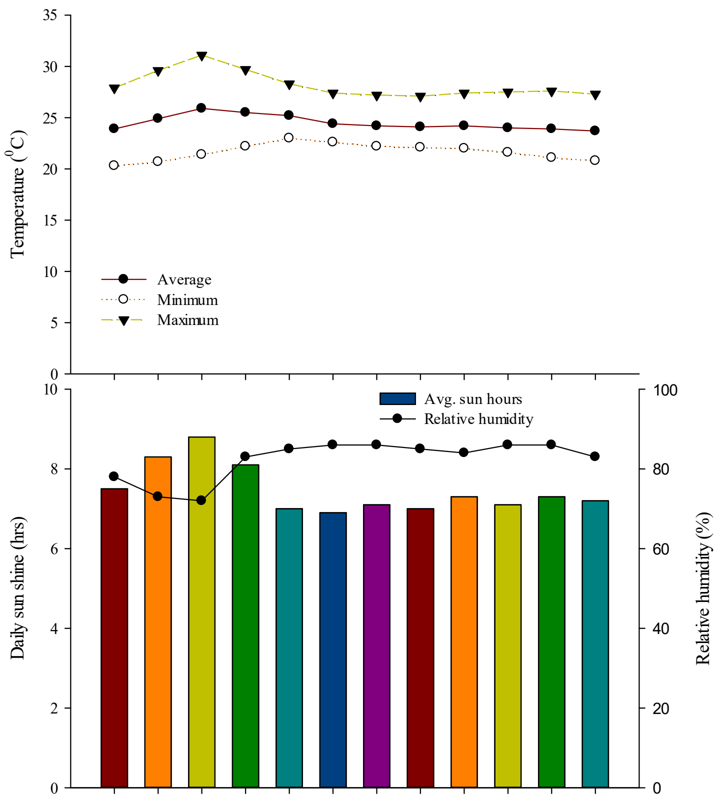

Figure 2: General climate of Rambukkana, Sri Lanka. Daily ambient temperature (top), daily average sunshine hours & relative humidity (bottom) (Data source: en.climate-data.org, accessed: 2022-12-21)

For the period 2012-2021, Wagolla research station, where rainfall data are recorded for the area, had recorded an annual average rainfall of 2008.6 ± 180 mm (Fig. 3). This shows at least 5% annual rainfall reduction in the last decade, when compared to long term average values for the area available in other data sources (Anon. 2022). Lowest rainfall records were reported in the months of January (43.7 ± 21 mm) and February (59.0 ± 22mm). However, months of July and August too can be considered as moisture critical months with low average rainfall. The total effective rainfall of the area, based on USDA soil conservation method, is 1310.4 mm (Narmilan and Sugirtharan 2021). The total annual water requirement for a mature tea plant is 1251 mm (FAO 2009). The highest water requirement is in the month of March. Months of January, February, July and August shows the necessity for critical supplementary water supply, as rainfall below monthly water requirement (Fig. 3).

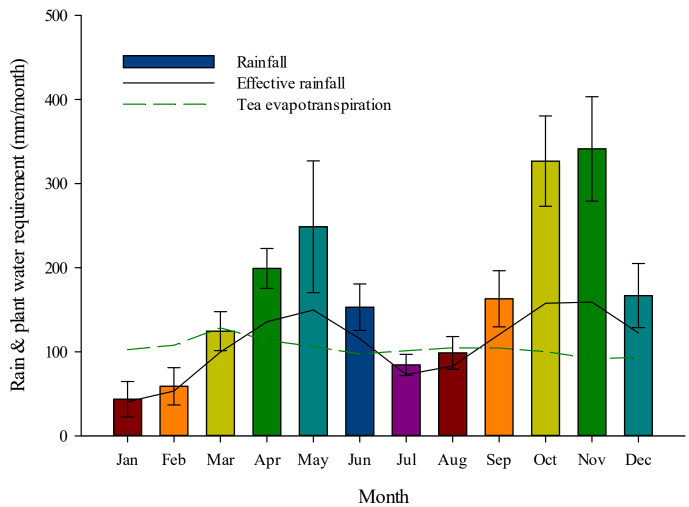

Figure 3: Average monthly rainfall for 2012-2021 period, monthly effective rainfall and tea plant potential water requirement (mm/month) (Data source: NRMC, Peradeniya)

Rainfall and Soil Moisture Availability in 2022

Year 2022 was an average year (with regards to total annual rainfall) for the experimental area, with a total annual rainfall of 2350.4 mm. Monthly distribution of rainfall and relevant effective rainfall is given in (Fig. 4). January and February months of the year were completely dry months, with almost no rainfall received.

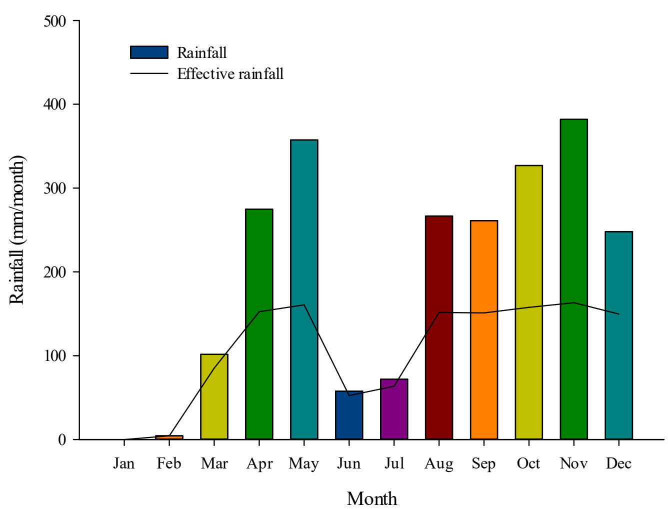

Figure 4: Total monthly rainfall and effective rainfall for 2022

Daily rainfall (in mm) and maximum potential soil moisture are given in Fig. 5. Only some months received well distributed rainfall. Other months received higher intensity daily rainfall events. There were 3 days receiving more than 100 mm rainfall within a day. These separate 3 days in September, November and December months have contributed for 16% of total annual rainfall of 2022. Tea Plants were subjected to severe moisture stress for the initial 03-month period of the year, according to the graph. Another few drought spells have been recorded in the period of July to October.

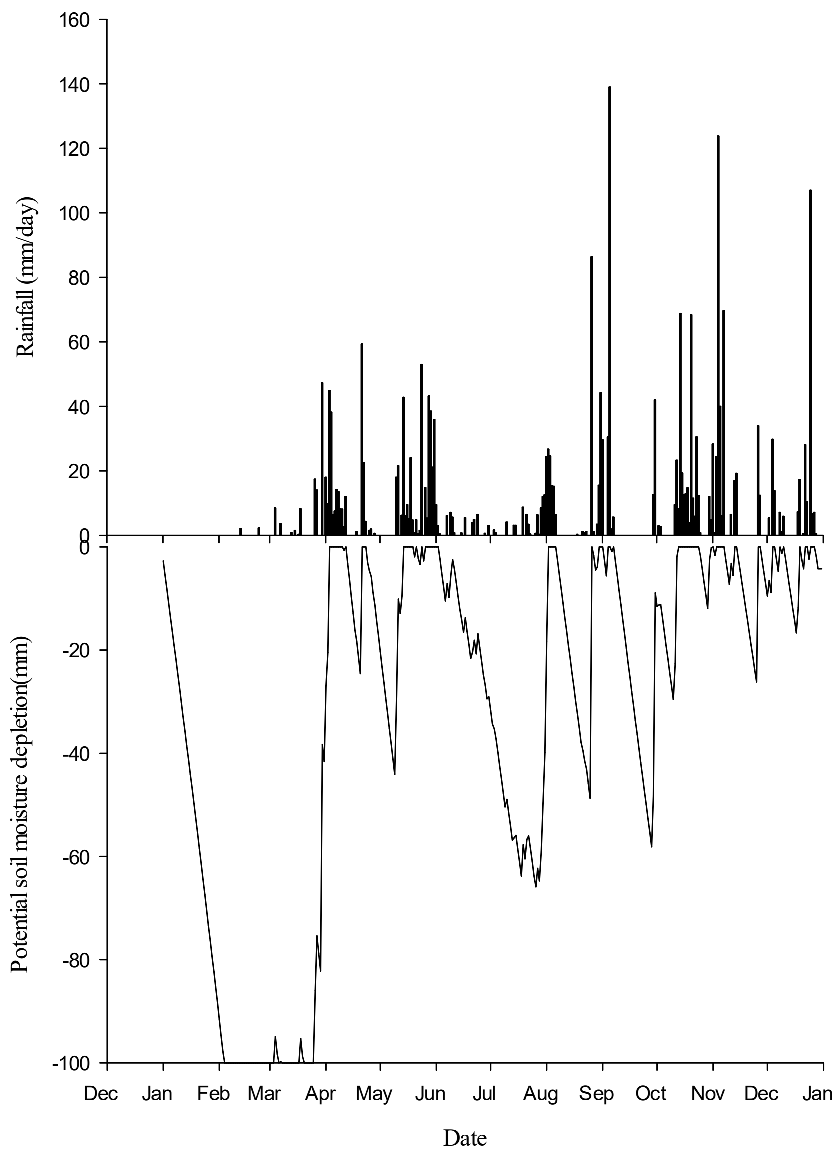

Figure 5: Daily rainfall and soil moisture depletion (%) in 2022

Physiological Measurements

Physiological measurements, recorded by ADC LC*pro* of topmost mature tea leaves, during mid-day are shown in Fig. 6. The average leaf temperature, during day time, recorded above 40^{0}C in most measuring days. This was consistent during the initial 4 months of the year, when dry weather prevails. However, average leaf temperature fell during the rainy season of the year. Stomatal conductance of the plants was much lower during the moisture stressed early months of the year (Fig. 6). However, it nearly doubled during the rainy months of the year.

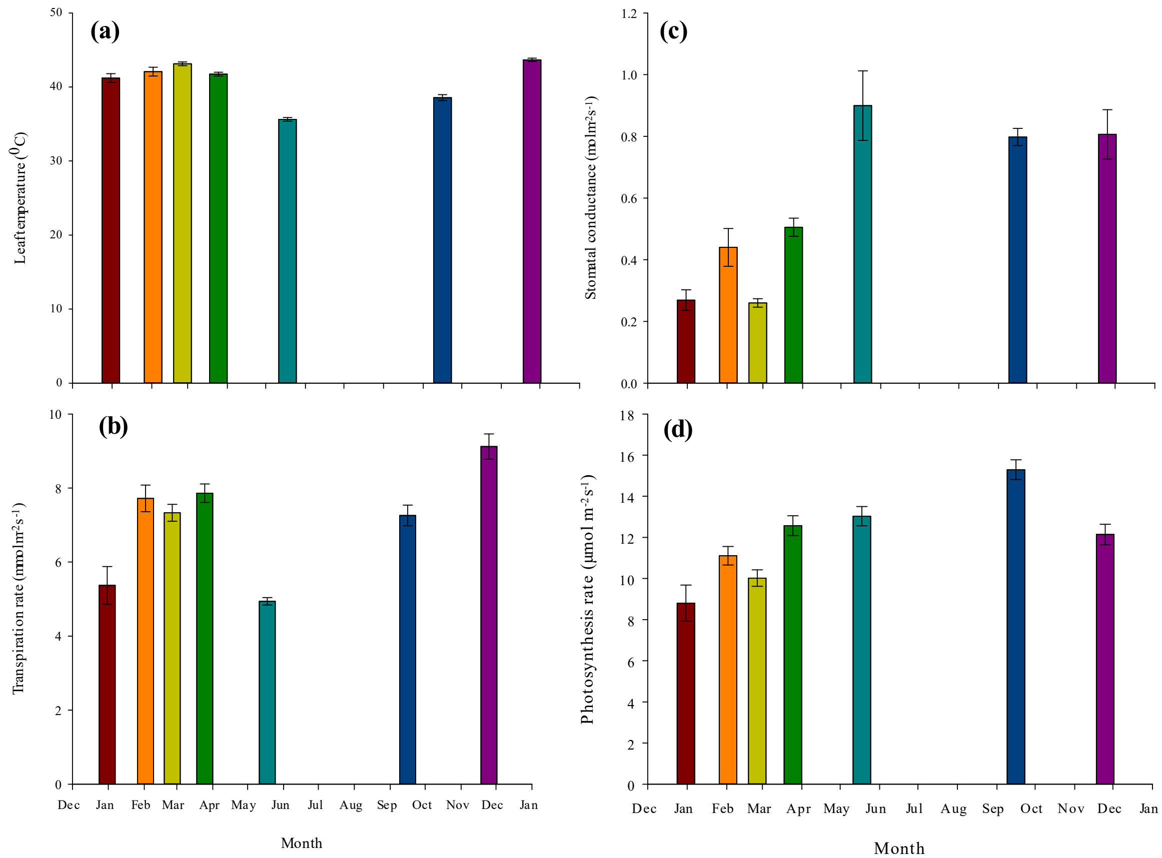

Figure 6: Physiological measurement of top most mature tea leaves, during mid-day (a)-Leaf temperature (^{0}C), (b)-Leaf transpiration rate (molm^{-2}s^{-1}), (c)-Stomatal conductance (molm^{-2}s^{-1}) and (d)-Photosynthetic rate (µmolm^{-2}s^{-1})

There was no significant reduction in transpiration rate of the tea plants during the dry season. However, the average photosynthetic rate increased by 24% during the wet season. Accordingly, water use efficiency of the plants increased by 30% during the dry season. The higher variation of some physiological measurements during the wet season could be due to variation of factors like solar radiation and air temperature.

Table 1: Average physiological parameters and water use efficiency of mature tea plants, during dry season and wet season

Measurement	Dry season	Wet season
Leaf temperature (^{0}C)	42.2 ± 0.19	39.2 ± 0.28
Transpiration rate (mmolm^{-2}s^{-1})	7.4 ± 0.15	7.1 ± 0.18
Stomatal conductance (mmolm^{-2}s^{-1})	0.388 ± 0.02	0.829 ± 0.04
Photosynthetic rate (µmolm^{-2}s^{-1})	11.04 ± 0.27	13.73 ± 0.30
Water use efficiency	1.49	1.93

When comparing the physiological activities of tea plants, during dry and wet season, as the plants were irrigated during dry season, there was less difference in all parameters, except stomatal conductance, with a significant increase (114%) in dry season (Table 1). The reason for this could be due to stomatal responses to hydraulic as well as chemical signals (Whitehead 1998) and vapor pressure difference (Morison and Gifford 1983). Reductions in tea plant physiological activities, like photosynthesis, even under irrigation during dry spells have been reported in other studies in low elevation tea growing areas of Sri Lanka (Bandara 2011). Also, the uncoupling of photosynthesis and stomatal conductance shows that irrigation effect, cushioning off the drought impact during dry season. In previous studies, it has shown that with progressive droughts, there is a relationship between stomatal conductance and photosynthesis in C-3 plants (Medrano, Escalona *et al.,* 2002).

Implications of Tea Cultivation in Non-conventional Areas

Even with a comparatively lower rainfall and higher ambient temperature regimes, tea cultivation has been an economical success (according to the owner) for nearly 15 years, since inception. The physiological measurements of the irrigated plants have shown that activities, like photosynthesis can be maintained successfully with minimum impact, during dry spells in the studied location, as similar to irrigated tea in low elevation growing areas (Bandara 2011). Operations of irrigation are done with minimum technical training and information, similar to many micro irrigation applicators. Micro irrigation for perennial crops is a relatively new development agriculture area for Sri Lanka, except for few studies (Liyanage and Mathes 1989, Ananthacumaraswamy 1995), unlike paddy cultivation (Narmilan and Sugirtharan 2021). The government's heavy investments on irrigation were mainly targeting major surface irrigation schemes, targeting paddy crop in dry and intermediate zones (Aluwihare and Kikuchi 1991, Kikuchi, Barker *et al.,* 2002). It is hence high time for analysing the benefits of establishing micro-irrigation facilities, for tea cultivation, with reservoir construction, as practised by early British planters, when establishing estates (Ukers 1935).

Boundary areas of present tea growing regions, especially in low elevation regions are mostly flat lands. Such flat lands would facilitate more opportunities for mechanization of agricultural practices. The mechanization of tea cultivation is largely restricted by the land topography (Sandeep, Gopinath *et al.,* 2011). There is a large scope not only for tea harvesting mechanization, but other machinery uses for land development, planting and other cultural operations. Specially, the use of tillage machinery, prior to planting could have the potential to reduce the soil rehabilitation time period (Bandara, Abeysekara *et al.,* 2019).

RECOMMENDATIONS AND CONCLUSION/S

The study revealed the ability of tea plants to survive in somewhat hostile growing conditions, with micro irrigation and proper agronomic practices. The adverse impact of dry season, with higher ambient temperature, on physiological processes, have been cushioned off with micro irrigation. No plant casualties were recorded during the dry season. Though, there is a chance for expanding tea irrigation with micro irrigation, more supporting schemes and studies are needed with necessary agricultural institutional changes.

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IDENTIFICATION OF NEW *COLLETOTRICHUM* SPECIES ASSOCIATED WITH THE NEWLY SPREADING CIRCULAR LEAF SPOT DISEASEOF (*Hevea*) RUBBER

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ABSTRACT

Colletotrichum is a widely spread fungal genus throughout the world including many severe plant pathogens. A large number of economically important crops are affected by different species of Colletotrichum. Colletotrichum leaf disease of rubber plantations is notable among them. Three new Colletotrichum species were mainly identified from the newly spreading leaf fall disease reported from Sri Lankan rubber cultivations. More than 500 disease samples were collected representing all the rubber growing agro climatic regions of the country. The symptoms were recorded and the causative pathogens were isolated on to Potato Dextrose Agar. The cultures were subjected to morphological studies and later for molecular identification. Cultural and reproductive characteristics showed a significant variability among the isolates. Based on morphological characters, 13 pathogen isolates were selected for further studies. DNA isolation was performed and PCR using the primers ITS 1 and ITS 4 was subjected. Sequencing revealed that there were three main species such as; Colletotrichum siamense, C. fructicola and C. gigasporum. Koch's postulates were proven with the three Colletotrichum specieson rubber seedlings. This is the first report of C. siamense, C. fructicola and C. gigasporum associated with the newly spreading leaf fall disease of rubber plantations. C. gigasporum was identified as a poor sporulator compared with the other two species. According to the pathogenicity studies, C. gigasporum showed the highest Disease Index value. A detailed study to investigate the biology and pathogenicity has been undertaken as the information is essential in the formulation of effective disease management strategies.

Keywords: C. gigasporum, C. siamense, Circular leaf spot disease, Colletotrichum fructicola,

INTRODUCTION

Natural Rubber is an important commodity to the world due to its multiple benefits to the society and to the environment. It generates export earnings, sustain the livelihood of millions of people, provides the most versatile raw material for numerous industries, essentially in the medical and automobile sectors, supplement thousands of hectares to the forest cover while providing many other socio economical and ecological benefits. A number of biotic and abiotic factors affects in reducing the yields of the rubber plantations. Among the biotic factors, fungal diseases are prominent. The scenario of the economically important diseases of the rubber cultivations has changed with time.

A new leaf fall disease spreading in rubber cultivations is becoming increasingly important in many rubber growing countries since 2018. The disease was first reported from Malaysia in the year 2018 and then from Indonesia. Later, the disease was reported from Thailand, China, India and Sri Lanka. By the year 2020, Indonesia showed an affected area approx. 380,000 ha, Malaysia 5000 ha, Thailand 52,000 ha and Sri Lanka 20,000 ha. Around 800,000 MT decline in their combined natural rubber production is expected in consequent years affecting rubber manufacturing industries. By today, the disease has spread to Vietnam and Myanmar too.

Colletotrichum species are important plant pathogens worldwide causing pre and post harvest losses on a wide range of economically important fruit and tree crops. The genus *Colletotrichum* contains fungal species of different life styles; biotrophic, hemibiotrophic, necrotrophic, endophytic or latent. Anthracnoses caused by new *Colletotrichum* specieshave become increasingly important in many parts of the world including Brazil (Henz *et al*., 1992), USA (Howard *et al*., 1992), France (Denoyes & Baudry,1995) and Japan (Sato *et al.,* 1996). *Colletotrichum* leaf disease of *Hevea* rubber is regarded as one of the major causes of declining yeilds of rubber in Sri Lanka (Petch, 1906; Jayasinghe *et al*., 1997), American and Indian Tropics, Thailand (Anon, 1960), China (Kaiming, 1998) and in West Africa (Senechal *et al.,*1987) The pathogen affects tender leaves causing die-back, shrivelling, and premature defoliation during continuous wet weather. The newly spreading circular leaf spot disease (CLSD) has devastated many high yielding rubber clones and has become one of the main economic factor in the rubber plantation industry.

All the rubber growing countries are making concerted efforts to detect the causative agent of the new disease and also to study the life cycle characteristics in view of developing effective disease management strategies. The CLSD was first reported from Sri Lanka during the latter part of 2019. Since then, more than five hundred disease samples have been collected. A detailed study is being undertaken to identify the causative agents of this disease. The present study reports of three new *Colletotrichum* species associated with this CLSD condition, their cultural and reproductive characteristics and molecular identification.

MATERIALS AND METHODS

Collection of pathogen isolates

The study was undertaken at the laboratories of the Plant Pathology & Microbiology, Rubber Research Institute of Sri Lanka. Diseased leaf samples were collected from different rubber growing districts (Table 1). The causative pathogens were isolated on to potato dextrose agar (PDA) after surface sterilization with 70% ethanol for 3 minutes.

The colonies appeared from the diseased tissues were transferred on to PDA and pure cultures were obtained by transferring several times.

Table 1: *Colletotrichum* isolates obtained from rubber plantations in different rubber growing regions of Sri Lanka

Isolate	Location	Clone	Lesion type	Species
C1	Dartonfield Mature field	RRIC 203	Brown circular lesions	*Colletotrichum siamense*
C2	Dartonfield Mature field	RRIC 121	Brown circular lesions	*Colletotrichum fructicola*
C3	Dartonfield Mature field	RRIC 110	Small brown coloured irregular lesions with a light colour center and dark colour margin	*Colletotrichum siamense*
C4	Miriswatta Mature field		Large circular lesions on yellow leaves	*Colletotrichum siamense*
C5	Mature field Miriswatta		Small circular lesions on green colour leaves	*Colletotrichum siamense*
C6	Ratnapura Bud wood nursery	RRISL 2001	Brown lesions with yellow margin	*Colletotrichum siamense*
C7	Ratnapura Bud wood nursery	RRIC 203	Brown lesions with yellow margin	*Colletotrichum fructicola*
C8	Walawwatta Mature field	RRIC 121	Slightly brown circular lesions	*Colletotrichum fructicola*
C9	Walawwatta Mature field	RRIC 121	Pin head size brown lesions	*Colletotrichum fructicola*
C10	Hillstream Mature field	RRISL 203	Brown circular lesions on yellow leaves	*Colletotrichum gigasporum*
C11	Hillstream Mature field	RRISL 203	Brown circular lesions on yellow leaves	*Colletotrichum siamense*
C12	Hillstream Mature field	RRISL 203	Brown circular lesions on yellow leaves	*Colletotrichum siamense*
C13	Dartonfield Mature field	RRISL 203	Brown circular lesions on green colour leaves	*Colletotrichum siamense*

Cultural characterization of the fungal isolates

Monoconidial isolates were made from 13 isolates of *Colletotrichum* collected from various genetic materials of *Hevea brasiliensis* and selected for further studies. Fungal cultures were maintained on PDA which had been identified as a superior medium for *Colletotrichum* (Fernando *et al*., 2000) and the cultures were stored under paraffin oil.

Colony growth on PDA

Petri dishes with PDA were inoculated centrally with a mycelia plug taken from the edge of 7 day old cultures. They were incubated under normal light and dark regimes for10 days at 27 ±2^0C. Two measurements of colony diameter were made at right angles to each other. There were six replicate plates for each isolate.

Cultural characteristics

Petri dishes with PDA were inoculated centrally with a mycelia plug taken from the edge of 7 day old cultures on PDA. They were incubated under normal light and dark regimes at RT room temperature for 10 days. At the end of the incubation period, the cultural characters were recorded.

Reproductive characteristics

At the end of 10 days of incubation period, cultures were observed microscopically for shapes and sizes of the conidia. The cultures were flooded with 10 ml sterilized distilled water. Surface of the cultures were mechanically disturbed with a glass slide without causing damage to the medium and filtered through a muslin cloth. Conidia count was obtained using the haemocytometer under the light microscope. Finally, the concentration of conidia suspension was recorded.

Above conidial suspensions were mounted on lacto phenol cotton blue (Difco). One hundred arbitrarily chosen conidia per different species were measured for their sizes using a micro-graticular, and the shapes of the conidia were also recorded.

Pathogenicity Test

Conidial suspensions (1 X 10^5 conidia/ml) were prepared from ten-days old cultures of each *Colletotrichum* isolate under investigation (C 1 - C 13) by re-suspending the conidia with 10 ml of sterilized distilled water per culture and conidial concentration was adjusted using a haemocytometer. Then, six rubber leaves of copper brown stage of the clone RRISL 121 were inoculated with six drops (15 µl per drop) of conidial suspension from each test isolate (C 1 - C 13). Another six leaves were maintained as the control by placing drops of sterilized distilled water. The inoculated leaves were incubated in a moist chamber at 28 °C and the symptoms were observed after three days of incubation under normal light and dark regimes. The sizes of the resulting lesions were ranked based on a visual scale. (0 - No lesion production; 1 –pin point size lesions; 2 –pin head size lesions; 3 –extended lesions but within the secondary veins; 4 –extended lesions with profuse growth of mycelia) (Lin *et al*., 2017).

Molecular characterization

DNA extraction and gel electrophoresis

The mycelium grown on PDA plates was scraped using a sterilized glass slide after 04days of incubation under normal light and dark conditions. They were ground in a chilled mortar and pestle and DNA was extracted from each culture following the protocol described in NORGEN Plant/ fungi DNA extraction kit (Product # E5038; Canada).

Extracted DNA samples were loaded to wells by mixing 5 µL of each extracted DNA samples with 2 µL of loading dye in 1.2% Agarose gel. It was run under 70V voltage with 100mA for 30 minutes. The gel was stained using Diamond Dye staining solution and it was observed under UV trans-illuminator. The gel pictures were taken using 'Quantum' software.

Polymerase Chain Reaction (PCR)

Amplification of ITS gene region was carried out using ITS1 (5′–TCC GTA GGT GAA CCT GCG G–3′) and ITS4 (5′–TCC TCC GCT TAT TGA TAT GC–3′) forward and reverse primers respectively. 5 µL of 5x PCR buffer, 2 µL of 25mM $MgCl_2$, 0.75 µL of 10mM dNTPs, 1 µL of 10µM Forward primer, 1 µL of 10µM Reverse primer, 0.5 µL of 5U/ µL *Taq* DNA polymerase, 2 µL of DNA template and 12.75 µL of Nuclease free water were used for one reaction. The total volume of 25 µL reaction mixture was used for PCR and it was carried out in a thermal cycler (Life ECO; Model- TC-96/G/H (b) C; Made in china). After an initial denaturation at 95°C for 2 min, 35 cycles of the following temperature conditions were used: 95°C for 30 s, 47°C for 30 s, and 72°C for 2 min. A final extension at 72°C for 5 min. was performed.

The gel electrophoresis was carried out at 70V, 300mA, 60 W for 60 minutes in a horizontal gel electrophoresis system (Labnet; Model- E0500; Made in Thaiwan). Amplified PCR products were separated by gel electrophoresis by mixing 5µL of the PCR product with 2µL of loading dye. Then those mixtures were loaded to wells in 1.2% Agarose gel which was prepared with 1M Tris-Boric EDTA solution and 100bp and1kb ladder (Promega, USA) was also added to another well. It was run under 70V, 300mA, 60 W for 60 minutes in a horizontal gel electrophoresis system (Labnet; Model- E0500; Made in Thaiwan). After electrophoresis, the gel was stained using Diamond Dye staining solution. After staining the gel, it was observed under UV transilluminator and the gel pictures were taken using 'Quantum' software (ST4).

Sequencing of PCR products

After observing the PCR bands selected samples were sent to Macrogen-Korea through Genetech-Sri Lanka for bi-directional sequencing.

Identification of isolates

Raw sequences were assembled using ContigExpress software. Sequence homologies for the assembled consensus sequences were analyzed using the BLASTn of the NCBI for the primary identification of fresh isolates used in the analysis.

RESULTS AND DISCUSSION

Colletotrichum gloeosporioides has been described as the causative agent of the *Colletotrichum* leaf disease since the early 1900's (Petch, 1906; Weir, 1926; Hilton & Hoh, 1959). Later, a study carried out in Sri Lanka in 1997 revealed that the fungus *C. acutatum* also played a significant role in the development of *Colletotrichum* leaf disease in Sri Lankan rubber plantations (Jayasinghe, *et al*., 1997). However recently, *C. simmondsii, C. laticiphilum, C. nymphaeae* and *C. citri* were also identified as causative agents for CLD in rubber by Hunupolagama and other sin 2017. However, major causative agents of CLD have been changed time to time.

This study was conducted with the spread of an unusually destructive leaf fall disease condition in main rubber growing countries of the world. The disease is reaching epidemic proportions with repeated leaf fall conditions and also reducing the yields. There are several species of *Colletotrichum* listed as quarantine pathogens. Hence, an accurate and fast identification of currently existing *Colletotrichum* species in rubber plantation is critical for the establishment of appropriate quarantine regulations and management practices (Crous *et al*., 2016; Jayawardena *et al*., 2016).

Characterization of the fungal isolates by cultural and reproductive morphology

Isolate C6 was isolated from a symptomatic rubber leaf with pin point lesions obtained from a bud wood nursery in Rathnapura area with severe infection of new leaf fall disease. And also, C7 was isolated from a leaf with pin point lesions with yellow margin in the same location. A symptomatic leaf with ash colour lesion was used to isolate C10 and the samples were supplied from Hill stream estate, Kalutara which was highly affected by the new leaf fall disease.

All the isolates showed significantly different cultural characters. All the colonies had circular shape, flat elevation, smooth and cloudy nature, entire margin and opaque nature. However, both upper and lower surfaces of C6 were pale white colony with orange colour conidiomata as rings. Upper surface of C7 was gray colour with yellow conidiomata at the middle while lower surface of the colony was white and gray colony with black and orange colour conidiomata. Middle of the upper surface of C10 was black and white in colour with white conidiomata and the edge of the colony was pale white. Middle of the lower surface was black and white in color with white conidiomata and the edge was pale white in colour.

Conidia were aseptate with one cell, green colour, smooth-walled, cylindrical, both ends rounded and granular. A clear area could be seen without granules at the middle of the conidia. The conidia size was about 13-16 µm x 4-6 µm. However, the spore production of *Colletotrichum gigasporum*is comparatively higher than other two isolates. Conidiophores were directly formed from hyphae which are septate and branched.

Appressoria couldn't be seen within 10 days incubation period. Mycelium of the isolate was septate and branched with 4-6 µm of width (Fig. 1).

Colony growth on PDA

Growth of each colony was approximately similar with slight differences. Numerical values of growth rates of *C. siamense*, *C. fructicola*, *C. gigasporum* were 0.9786, 1.0214, 0.9857 cm/day respectively (Fig. 2). Growth rates of each isolate were also approximately similar in PDA.

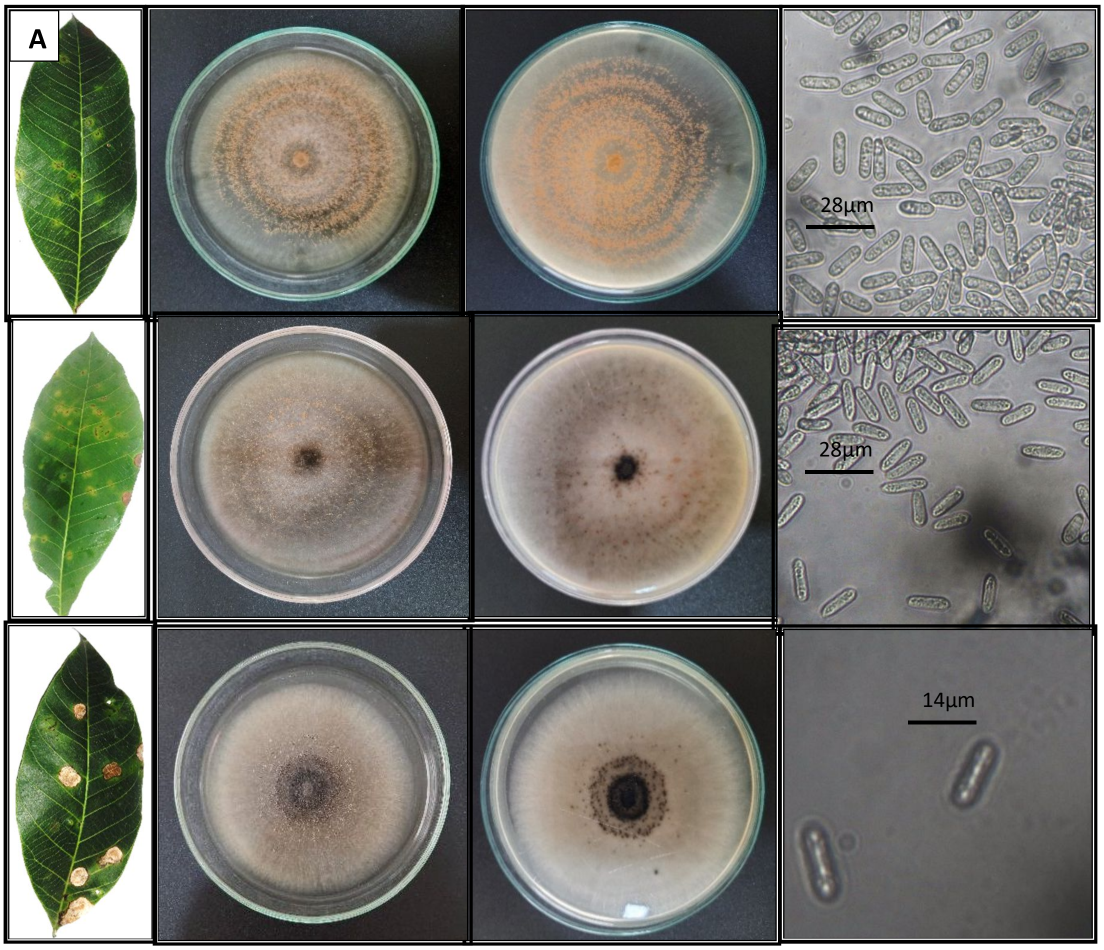

Figure 1: A: Isolate C6 – *Colletotrichum siamense*; B: Isolate C7- *Colletotrichum fructicola;* C: Isolate C10 – *Colletotrichum gigasporum*– from left to right: Symptomatic leaf, colony morphology upper & lower surfaces, shape & size of conidia.

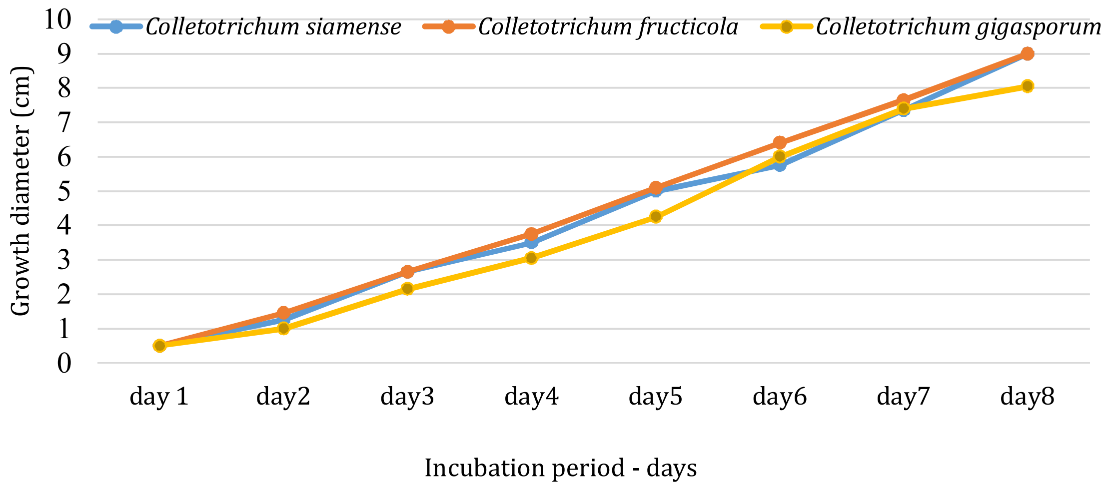

Figure 2: Growth of the *Colletotrichum* cultures under investigation on PDA after 8 days of incubation period at RT

Pathogenicity Tests

The pathogenicity test is important to estimate the severity of the pathogen before making management decisions. Both isolates were pathogenic to rubber while their levels of pathogenicity varied. In the pathogenicity test, with the inoculation of the conidia suspension, the pathogen can contact with the host. After contacting the host with the conidia of the pathogen, they start to germinate with the favourable environment and form germ tube. Penetration and colonization of *Colletotrichum* sp. in the host tissue initiate with the germination of conidia and the formation of specialized infection structure called appressoria. It facilitates the entry of the pathogen through the host cuticle and epidermal cell walls with the aid of narrow penetration pegs (Wharton and Schilder, 2008).

Developing lesions on the rubber leaves for each isolate were recorded (Fig. 3). All the non- wounded leaves treated with the conidial suspensions (10^5 conidia/ml) of each isolate exhibited different levels of lesions except the control. Germinating conidia were present in each drop of conidia suspension when observed under the microscope. *Colletotrichum siamense* showed the lowest DI value (1.813) while both *Colletotrichum fructicola* and *Colletotrichum gigasporum* showed approximately similar higher DI values (2.4491 and 2.5021 respectively) (Fig. 4).

Figure 3: Production of lesions on the non- wounded rubber leaves which were treated with conidial suspensions (10^5conidia/ml) of each isolate - C6 (*C. siamense)*, C7 (*C. fructicola),* C10 (*C. gigasporum)* and non-wounded leaf with sterilized distilled water drops as the control.

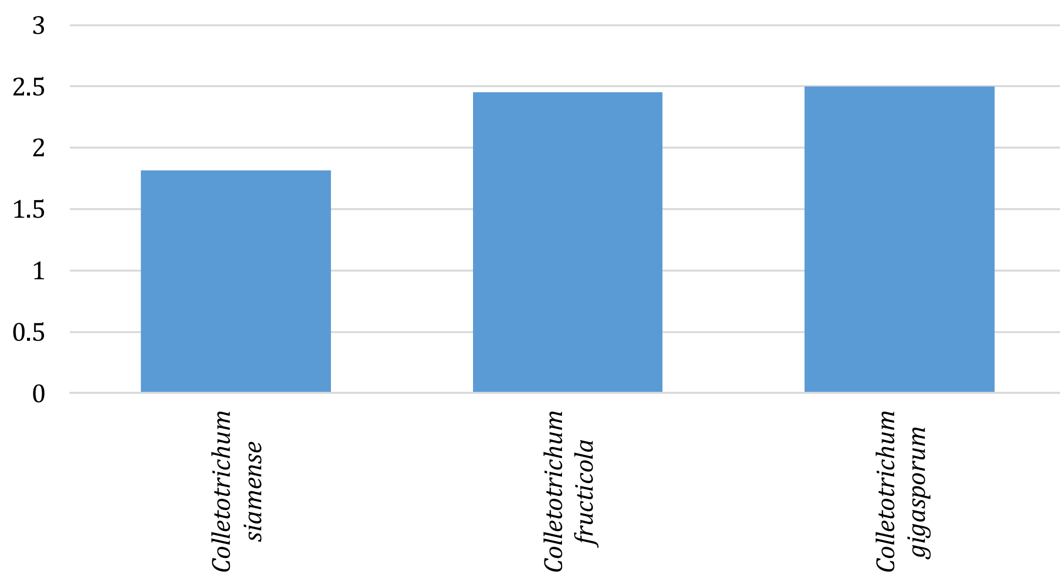

Figure 4: Disease Index values of each isolate after artificial inoculation of the detached leaves – clone RRIC 121. The bar denotes standard deviation (P ≤ 0.01)

According to the results of the current study, *C. gigasporum* showed the highest pathogenicity to the rubber leaves resulting 2.50 DI value. *C. siamense* showed the lowest DI value (1.813) while *C. fructicola* behaved as a moderate level pathogenic species showing 2.45 DI value. Although the spore production rate is low in *C. gigasporum,* pathogenicity is higher than other two isolates. However, the severity of *C. gigasporum* can be estimated as comparatively high.

Molecular *characterization*

Molecular techniques are important for the accurate identification and delineating of species boundaries of the pathogens. Morphological characters, pathogenicity information, conidia production, and fungicide sensitivity are critical for understanding the behavior of the pathogen and the identification of new species (Cai *et al*., 2009). Therefore, further studies for the pathogenic *Colletotrichum* species are very much essential and timely needed. After performing BLASTn in NCBI data base, each isolate was identified up to species level which having highest similarity with the compared sequences. According to the highest identity values in NCBI BLAST results, isolate C6 was identified as *C. siamense,* C7 was identified as *C. fructicola* while C10 was identified as *C. gigasporum.* However, identification and characterization of new pathogen related to a new disease is critical as the identified pathogens may cause severe damages to other economically important hosts too.

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CHALLENGES AND OPPORTUNITIES OF FRAGMENTATION OF TEA ECONOMY IN DARJEELING TEA, INDIA

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ABSTRACT

India's tea economy has undergone structural changes in recent decades, and Darjeeling Tea experiences the same pattern. There is a sizable presence of smallholders since the 1990s in addition to 87 estate gardens registered under GI (2004). Now it may not be identified as Integrated Enterprise (estate gardens) where production, processing and marketing are done as composite unit. This has changed the plantation landscape in terms of production behaviour, employment scenario, and land use pattern and demands new policy regimes. The older estate gardens face low productivity due to bush age which led to the high cost of production added by rising input costs. Many gardens are abandoned and on the verge of closure which requires replanting and government support to safeguard the livelihoods of the labouring community. The Darjeeling Tea also experienced a bad phase due to the Gorkhaland agitation of 2017 and the production level was reduced to almost 50 per cent since then. It is found that there is a flow of Nepal tea in Darjeeling hills and being sold to the international market in the name of Darjeeling Tea. This has affected the quality of production and low market realization of made tea. Interventions are therefore needed to protect both the tea sector and the Labourers from the crisis. Techniques like replanting, cluster marketing, public funding, etc. can be encouraged in the region.

Keywords: Darjeeling tea, Estates, Smallholders, Tea economy

INTRODUCTION

India is one of the oldest plantation regions in the world (Sen, 2015). It supports 1.2 million people in the country through direct employment and additionally 10 million people through indirect engagements (Saha *et al.,* 2019; Chattopadhayay, 2022). Among the major tea-producing countries namely Bangladesh, Sri Lanka, Kenya etc. India is one of the largest tea producers and consumers. The first tea industry in India began in 1839 under colonial rule in the state of Assam and it soon expanded to other parts of the country (Mishra *et al.,* 2016). The major tea-growing regions of India are West Bengal, Assam, Tamil Nadu, Kerala, Karnataka etc. After the disintegration of the Soviet Union, the Indian tea industry faced severe setbacks as it was one of the major importers. Other factors like an increase in domestic demand, a decline in exports, cheaper tea imports from other countries, labour crisis, ageing tea bushes etc. are considered to be the triggering factor for the crisis of the tea industry in India. The challenges are not only faced by the labourers of closed gardens but also the operating tea gardens due to low wages and poor working conditions (Chattopadhayay, 2022; Hannan and Golay, 2022).

Among other tea-growing regions of India, *Darjeeling tea* of West Bengal holds prominent importance. Due to its distinctive flavour and aroma, the tea produced in the area is well-known across the world. Darjeeling tea has been accorded Geographical Indication (G.I) status since 2004 (Tea Board of India) so that the tea produced in the region is recognized and cannot be duplicated elsewhere outside of the region. The Darjeeling tea plantations are not an exception to the ongoing issues and challenges facing by the tea industries.

Saha (2020) has highlighted that there are two types of plantations in India i.e., large plantations and the Small Tea Gardens (STGs). Underlining the challenges faced by the tea plantations in India the literature highlights the shifting of the tea economy from an organized model to STGs which has direct implications on the industry and Labourers as well (Mishra *et al.,* 2016, Sankrityayana, 2018). Similarly, the growth of STGs is also found in the Darjeeling tea region. Besides as highlighted in the recent news daily that the existing market conditions, high production cost, old bushes, low productivity, labour constraints, impact of Nepal tea as well as the impact of climate change have huge impacts on the tea plantation of the region (Chattopadhayay, 2022). Under the Plantation Labour Act (1951), labourers agreed to various provisions and protections like health and education facilities, drinking water, sanitation, fringe benefits, etc. Thus, these acts provided the labourers' bargaining power to the authorities (Mishra *et al.,* 2016). The smallholders do not qualify as plantations because they are less than 25 acres in size. Whereas, STGs are not covered by the PLA's provisions, and the restructuring of the tea industry using STG principles has made life miserable for plantation labourers, which has a negative influence on their real wages (Sankrityayana, 2018).

Darjeeling is situated in the state of West Bengal, India. The 87 tea gardens are distributed in the four sub-regions i.e., 43 (49 per cent) out of 87 tea gardens are situated in the Darjeeling sub-division, 28 (29 per cent) of tea gardens in the Kurseong sub-region, 10 (12 per cent) in the Mirik sub-region and 6 (7 per cent) in Kalimpong sub-region (Fig. 1). They cover a tea plantation area of about 20441.04 hectares and produce 5565281 kgs of tea altogether (2019). The number of Labourers employed in these tea gardens is 44656 (Trade union office; DTA 2020; Golay 2021).

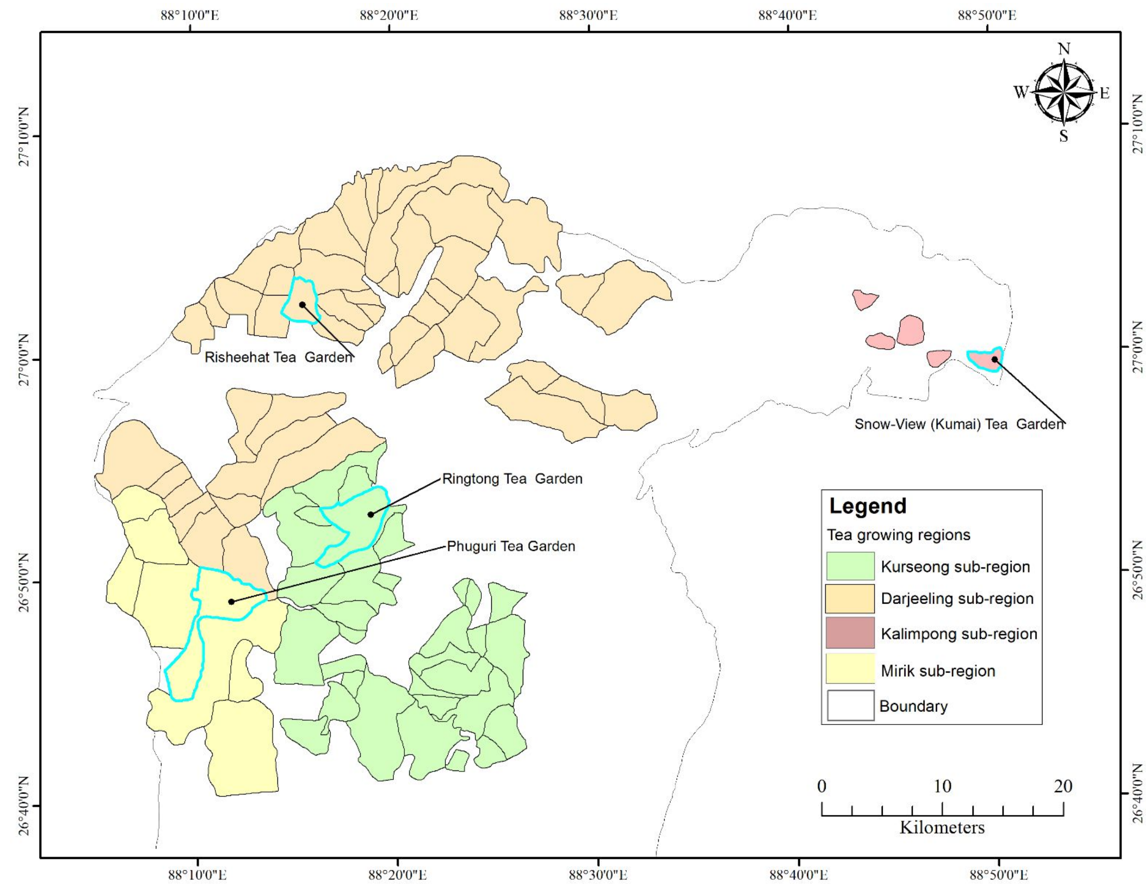

Figure 1: ***Darjeeling Tea*** **and its Sub-Regions**

Source: Prepared by author, 2022 (Based on Map of Darjeeling Tea Association, Kolkata)

Objectives

1. To analyze the pattern and estimate the levels of employment in the estate sector of Darjeeling Tea;
2. To investigate the working conditions and labour relations in the emerging smallholders' sector in Darjeeling Tea;
3. To evaluate the recent land diversification policy on the tea sector and its impact on tea labour;
4. To identify the challenges and suggest measures to overcome the crisis faced by Darjeeling Tea.

MATERIALS AND METHODS

The primary data is gathered from four estate gardens and four smallholder's gardens, each from all four sub-regions (Table 1) using the purposive sampling technique. The field survey was carried out in August-December, 2022. The tea estate managers and the small-holder garden owners were the subjects of the study and interacted through open-ended questionnaires. Views of management concerning locational factors of factories, settlements, marketing system, casualization of Labourers, the disintegration of tea gardens and growth of STGs and the land diversification policy of the Government of West Bengal were taken into consideration. In addition, information about land use, production level, the number of Labourers employed, and health care and educational facilities was gathered and analyzed.

From secondary sources, data of 87 tea gardens were collected, production data for the year 2000 and 2019 and aspects like per unit labour absorption, land productivity, production per unit of land, land and labour ratio, and land and staff ratio have also been computed and discussed. Also, grant area, plantation area, annual production data (2016-2021) from four estate garden has been collected and analyzed. Labour productivity is calculated by dividing total production by no. of Labourers. Production per unit of land is calculated by dividing the production of the area. The labour and staff ratio are calculated by dividing no. of Labourers by no of staff. The land labour ratio is calculated by dividing no. of Labourers by the plantation area. Landy and staff ratio is calculated by dividing the plantation area by no. of staff. Statistical techniques like mean ($= \Sigma xi/n$), Standard Deviation (SD=√Σ(−)2/n), Coefficient of Variations (CV = $\frac{SD}{Mean} * 100$) has also been calculated and analysed to understand the intra-variations of tea estates within sub-regions and inter-variations of the sub-regions. The annual growth rate of wages (2012-2022) was computed, Growth Rate (%) = $Present\ year - Past \frac{year}{Past} year * \frac{100}{no} of\ years$

Table 1: Profile of the Surveyed Estate and Smallholder Gardens in Darjeeling Hills

Estate Gardens (Organised Sector)										Smallholders (Unorganised Sector)					
						Labour		Wages (Rs.)							
Sub-Regions	Garden Name	Estd. of Garden	Grant Area (ha)	Tea Area (ha)	Area Under Tea (%)	Male (%)	Female (%)	Field	Factory	Name of the Garden	Year of Estd.	Area (acres)	Annual Production (Kgs)	Wages (Rs.)	Whether Has a Factory?
Darjeeling	Risheehat Tea Garden	19th century	388.19	256.45	66.06	265 (31.47)	577 (68.52)	232	240.5	Nirola Farms	1999	7	14000	250-350	Yes
Kurseong	Ringtong Tea Estate	1865	835.16	338.12	40.48	137 (37.53)	228 (62.46)	232	240.5	Ten Tshering Lepcha	2002	9	-	180-200	No
Kalimpong	Kumai Tea Garden	1869	587.62	313.62	53.37	238 (33.56)	471 (66.43)	232	240.5	Adarsh Muna Tea Garden	1995	18	-	200	No
Mirik	Phuguri Tea Garden	-	427.41	227.68	53.26	123 (26.62)	339 (73.37)	232	240.5	Yanku Small tea farm	2000	3	10000	250-400	Yes

Source: *Computed from Unpublished data Collected during field survey, August-December 2022*

RESULTS AND DISCUSSION

Pattern of Darjeeling Tea

Table 2 shows the Pattern of Darjeeling Tea, it is subdivided into four sub-regions i.e., Darjeeling, Kurseong, Mirik and Kalimpong. It is found that among the sub-regions the land productivity (yield) is highest in the Mirik division followed by Kalimpong, Darjeeling and Kurseong with 666.54 kgs, 296.02 kgs, 240.87 kgs and 171.59 kgs respectively. It may vary among the regions based on their geographical factors, climatic conditions, age of the bush etc.

Also, it can be deduced from the production data for the two time periods, 2000 and 2019, that the sub-region of Darjeeling Kurseong and Kalimpong produced less in 2019 than it did in 2000. While the production in the Mirik sub-region has increased from the year 2000 (Table 2; Fig. 2). This may be also due to the prevalence of STGs in the region contemporarily.

On the other, Labour Productivity and production both are more in the Darjeeling sub-region as there is a greater number of Labourers employed as a greater number of tea gardens situated in this division as compared to other divisions. The Labour staff ratio is 1:9 in the industry collectively. The land labour ratio of the four divisions is calculated which may determine the wages of the labourers, if more land is available per Labourers, they will be able to produce more output adding to their wages and vice versa. The land labour ratio in Darjeeling Tea Industry is 1:2 i.e., which means one labour covers two hectares of land. The land and staff ratio are 1:4 i.e., means one hectare of land has four number of staffs in the industry who has only a supervisory role to manage the garden.

The computed Coefficient of Variation (C.V.) between the various sub-regions for grant area, plantation area, production, number of employees, and number of staff and sub-staff is 69.60 per cent, 72.33 per cent, 57.61 per cent, 73 per cent and 78.44 per cent respectively. The fact that none of the figures are more than one, or 100 per cent, shows that the standard deviation is higher than their mean value.

The C.V. within each sub- region's has also been determined. The Darjeeling region's C.V. for Grant Area is 71 per cent Kurseong is 141.60 per cent, Kalimpong is 29.66 per cent, and Mirik is 38.10 per cent. Only in the Kurseong region the C.V. surpass 1 or 100 per cent, indicating that the standard deviation is higher than the mean value. Other indicators like plantation area, production, number of employees, and staff and sub-staff numbers have C.V. that are less than 1 or 100 per cent.

Table 2: Profile of Darjeeling Tea Industry, 2019

Sub-regions	Grant Area (Ha)	Plantation Area (Ha)	No. of Gardens	Production 2000 (Kgs)	Production 2019 (Kgs)	No. of Labourers	No. of Staff and sub-staff	Total Workforce	Labour productivity (Per Person)	Production per unit of Land (Ha) 2019	Labour and Staff ratio	Land and Labour ratio	Land and Staff ratio
Darjeeling	23371.34 (49.24)	10773.16 (52.70)	43 (49.43)	4546401 (54.42)	2594994 (46.63)	24202 (54.19)	2982 (56.71)	27184 (54.46)	107.22	240.87	1:8.11	1:2.25	1:3.61
Kurseong	15944.56 (33.59)	5988.09 (29.29)	28 (32.18)	2275557 (27.24)	1027519 (18.46)	11623 (26.03)	1285 (24.43)	12908 (25.86)	88.40	171.59	1:9.05	1:1.94	1:4.66
Kalimpong	2996 (6.31)	1376.36 (6.73)	6 (6.89)	532283 (6.37)	407429 (7.32)	2792 (6.25)	241 (4.58)	3033 (6.07)	145.93	296.02	1:11.59	1:2.02	1:5.70
Mirik	5148.663 (10.85)	2303.43 (11.27)	10 (11.49)	1000487 (11.98)	1535339 (27.59)	6039 (13.52)	750 (14.26)	6789 (13.60)	254.24	666.54	1:8.05	1:2.62	1:3.07
Total	47460.56 (100.00)	20441.04 (100.00)	87 (100.00)	8354728 (100.00)	5565281 (100.00)	44656 (100.00)	5258 (100.00)	49914 (100.00)	124.63	272.26	1:8.49	1:2.18	1:3.89

Source: Unpublished data collected from Darjeeling Tea Association; Trade Union Office Darjeeling during the field survey, Dec 2020; Golay, 2021.

[Notes: The production data is based on the data collected from Darjeeling Tea Association for two time periods i.e., 2000 and 2019. Some of the production data of the garden were missing or were not reported to the DTA office and hence, the aggregate of reporting gardens is taken into account as the total for each sub-region.]

Perspectives on Estate Gardens

Land use and Resource Utilization

The land in the tea gardens of Darjeeling hills is owned by the Government of West Bengal which is sold or given on lease for about 30 years or more which can be renewed after the expiry date of the lease (Datta, *et. al.,* 2010). Land was ideally used for tea plantations and required constructions like factories, Bungalows, Labour Quarters, Schools, Dispensaries etc. and the labourers working in the gardens for last six generation do not enjoy land rights. As the tea industry is undergoing crisis recently the Government of West Bengal has allowed the tea plantation owner to use 15 per cent of the total leased land or grant area for tourism and related business operations to maximize the profit (The Kolkata Gazette, 2019).

As given in table 3 approximately 50 per cent of the leased area is covered by the tea plantation and remaining areas are covered with forest, labour line, dispensary, factory, bungalows etc. which are also essential for the functioning of these tea gardens. The managers stated that they are proposing to practice tourism in the unused land of the tea garden as per new policy of the Government. But unused land or barren lands are found to be absent in these estate tea gardens. Thus, either tea planted areas or the other areas like forests, bamboos etc. have to be cleared for such operations.

The managers regarding the new policy they stated that, "through the 15 per cent land grant Government is indirectly trying to help out tea industry to make a profit through tea tourism. Besides investing in the tourism project also requires expenses from the company and every garden company is not capable of doing such investments. Such as, "the Bansal Group[1]", they cannot invest in tourism as they were not even able to pay wages of the labourers as stated in a news daily (Banerjee, 2022). As argued not many gardens can do it unless given loans from the government. Limited gardens like Sourini, Glenburn, Charmuni, Singtam etc. have opted for tourism. Moreover, as argued tea tourism is not a permanent solution for the ongoing crisis of Darjeeling tea industry because one cannot look at both tea and tourism as one. Moreover, as stated in the news daily many planters and Labourers are afraid that the tea sector will be neglected as a result of government policy (Chhetri, 2022). They stated that main priority is tea and it should be the main focus and such investments can be made in the tea industry itself. The managers suggested that uneconomic tea bushes should be removed and quality clones should be introduced as all markets demand quality tea.

[1] Bansal Group is one of the owners of tea gardens in Darjeeling Hills. Under this company 10 tea gardens were shut down following the loss in the sector and labourers agitation due to irregular wages and benefits in 2022.

Table 3: Pattern of Land use and land cover of selected tea gardens (in hectares)

Land use/Land cover	Ringtong	Risheehat	Snow-View (Kumai)	Phuguri
Tea Area	338.12 (40.49)	256.45 (66.06)	313.62 (53.37)	227.68 (53.27)
Road	-	3.64 (0.94)	-	29.03 (6.79)
Jhora/River	-	14.21 (3.66)	84.23 (14.33)	13.39 (3.13)
Jungle	-	72.68 (18.72)	-	92.32 (21.60)
Forest	-	-	2.66 (0.45)	-
Village/ Cultivation Area	-	-	121.03 (20.60)	-
Thatch	-		9.19 (1.56)	-
cardamom	-	0.36 (0.09)	40.26 (6.85)	-
School	-	0.08 (0.02)	-	1.35 (0.32)
Ground	-	0.52 (0.13)	-	
Bungalow	-	0.94 (0.24)	-	0.85 (0.20)
Factory	-	0.4 (0.10)	-	0.48 (0.11)
Temple/church	-	0.14 (0.04)	-	0.18 (0.04)
Dispensary	-	0.2 (0.05)	-	0.12 (0.03)
Bamboo	-	1 (0.26)	16.63 (2.83)	2.97 (0.69)
Labour Line	-	37.57 (9.68)	-	55.28 (12.93)
Graveyard	-	-	-	0.72 (0.17)
Shop/Dokan	-	-	-	3.04 (0.71)
Grant Area	835.16 (100.0)	388.19 (100.0)	587.62 (100.0)	427.41 (100.0)

Source: C*omputed from the data collected from respective tea garden office, August-December 2022.*

Likewise, earlier the production of Darjeeling tea had the production of 13-14 million kg production and which has been reduced to 6-7 million kg. there are more than 150 years old bushes and replantation is not practiced efficiently. Besides the political scenarios of the region also plays a major role in the decline of tea industry.

As per the field survey, it was found that during the agitation year[2] i.e., 2017 the tea production in Darjeeling was affected and it was reduced to less than 50 per cent (Fig. 3; Table 4).

As stated, the agitation of 2017 has also hampered the relationship of Darjeeling tea gardens with many foreign buyers ("GJM Ends 104-Day Strike: All about Darjeeling Crisis, Gorkhaland Demand," 2017). Most of the gardens lost good buyers who used to provide better prices. They had certain fixed buyers and also had fixed agreements with them. So, in 2017 gardens of Darjeeling could not supply sell tea to their buyers and as buyers also have agreements with others, they were compelled to take other options. They shifted to China, Sri Lanka etc. thus they lost a big chunk of buyers who provided good prices. And since 2018 normalcy came in the region and they had to look for new buyers some of the gardens which have marketing experts survived, and those that do not, have suffered.

Thus, Tourism may run well and support the tea industry as an alternative but the political situation in the region is also uncertain

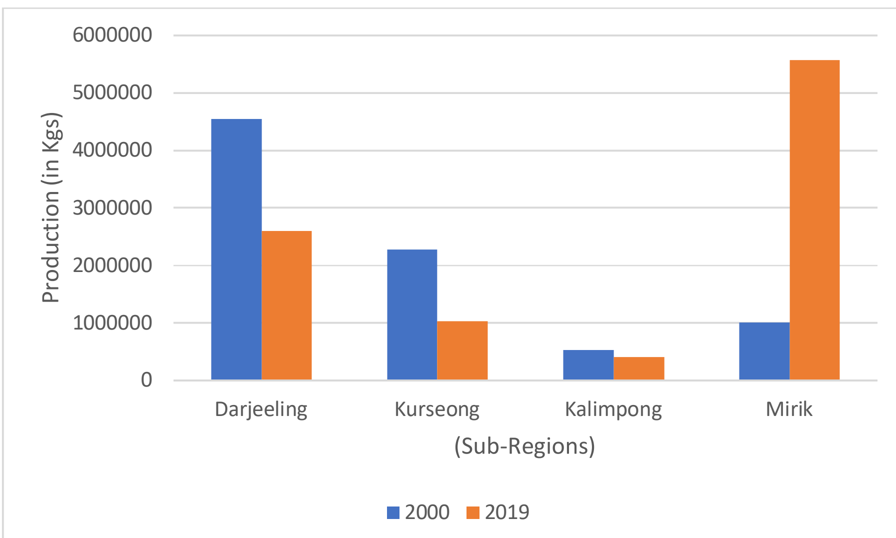

Figure 2: Sub-Region wise Production of Made Tea (2000-2019)

[2] Darjeeling has been a politically hostile region since long, the agitation of 2017 was mainly related to the demand of separated land by the people of the region from the Government of West Bengal. Thus, during June-September, 2017 a shutdown was called out by the then ruling political party in the entire region for a period of 104 days.

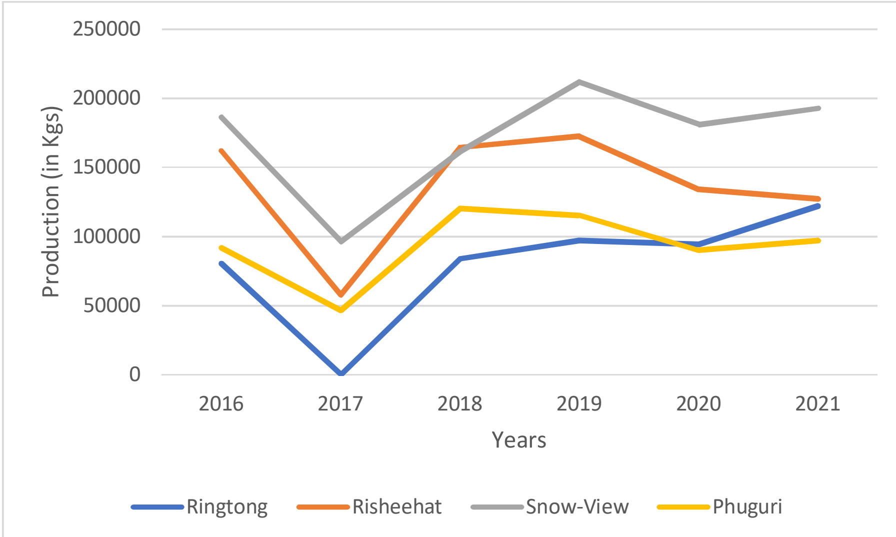

Figure 3: Production of Made Tea of Selected Estate Garden (2016-2021)

In the tea gardens, the location of the factory is important as per the local geographic conditions, particularly with slope and topography. Since the British period, most of the tea gardens in Darjeeling have had their factory locations on the down slope strategically mainly for hydropower to generate electricity to run the machinery. In the current scenario, the factory in Ringtong tea garden is run by Liquid Petroleum Gas, in Risheehat tea garden electricity, and by coal in Kumai Tea Garden and Phuguri Tea Garden. Thus, the generation of hydroelectricity can be rejuvenated in the tea gardens of Darjeeling Hills as a cost-cutting measure.

Table 4: Production of Made Tea (in Kgs)

	Years	2016		2017		2018		2019		2020		2021	
Years	Area (Ha)	Production (Kg)	Yield (Kg)	Production	Yield	Production	Yield	Production	Yield	Production	Yield	Production	Yield
Ringtong Tea Garden	338.12	80447	237.92	-	-	84000	248.3	97005	286.9	94505	279.5	122100	361.11
Risheehat Tea Garden	256.45	162140	632.25	57736	225.14	164342	640.83	172615	673.09	134045	522.69	127022	495.31
Snow-View Tea Garden	313.62	186457	594.53	96274	306.98	161507	514.98	211935	675.77	181265	577.98	192842	614.89
Phuguri Tea Garden	227.68	91710	402.8	46500	204.23	120399	528.81	115247	506.18	89945	395.05	97138	426.64

[Note: Ringtong Tea Garden was closed during the agitation year (2017) and there was no production]

Source: *Computed from Unpublished data Collected during field survey, August-December 2022*

Working Conditions (Physical and Financial)

The Plantation Labour Act (1951) was passed in India to protect the rights of labourers and to ensure their well-being. As per the provisions, the tea garden is required to offer amenities such as canteens, daycare centres, recreational areas, accommodation, drinking water, health care etc. The workers lack the aforementioned amenities and receive meagre wages that are insufficient to cover their daily needs. According to Mishra *et al.,* (2016) and Xaxa (2019), the working conditions for labourers have been appalling since the tea industry began. As a result, it is characterised as an enclaved economy (Dasgupta, 1983) that is prevalent with worker poverty, management exploitation, and harsh working conditions.

These sample Tea Gardens has 2378 labourers of which 1615 are female and 763 are male (Table 1). The garden is facing 35-40 per cent labour absenteeism as per the interview.

Labourers are paid through a tripartite agreement basis and their wages are hiked as per settlement of agreements from time to time. Whereas management staff's monthly salary varies from Rs. 8000- Rs. 24000 among these gardens. The current wage of field labour and factory varies and it is Rs.232/ and 240.50/- per day. The work schedule is for 7-8 hours with a break of one hour and varies among the tea gardens. Field labour is given the task of plucking an average of 8-16 kg of green leaf /per day which also varies among tea gardens depending on the season. The harsh works are operated by the males and the females are indulged in other lenient works.

As stated, the supply of Labourers had increased in these gardens during the pandemic. But in recent years there is around 25 - 30 per cent of labour absenteeism and it is increasing due to out-migration due to the closure of the gardens. As per the local information and the news daily (Banerjee, 2022) 10 tea gardens in the Darjeeling hills were abandoned which has been a common phenomenon in the tea industry. Besides due to the poor working condition, lower wages, lack of basic amenities etc. the labourers are out-migrating of the tea garden areas. Also, due to the increasing literacy among the labouring household, the new generation is not willing to work in the tea gardens.

As mentioned by one of the managers one of the biggest constraints that the Darjeeling tea industry faces is labour constraint. There is increasing number of labour absenteeism in the tea gardens so it is very difficult to run the industry. As stated, they are outsourcing the labourers and i.e., not a permanent solution. Thus, the casualization of the labourers is increasing and it has also been stated in a news daily (Singh, 2021). Thus, if tea gardens are maintained well through government interventions the labourers do not have to migrate outside for petty work.

Marketing

Auctions have been the main platform for tea marketing in India (Saji, 2005; Hannan, 2017). The supply chain models followed by the gardens in Darjeeling Hills are mainly Private, Auction, and Export Sales (Fig. 4) with their relative share of 40, 30 & 30 per cent respectively.

As stated during 1st flush 90 per cent is exported, in 2nd flush, 60-65 per cent is exported, in the monsoon flush, 25 per cent is exported during autumn and 50 per cent is for auction sale. The tea production is transported to the Siliguri tea warehouse and then to Kolkata. The transportation cost depends on the means of transport. The supply chain of the gardens is Tea-Factory-Processing-Siliguri (Warehouse)-Kolkata (Auction). The brokers like J-Thomas Company, Contemporary Tea Broker, Pakur farm buyers etc. do auctions. Usually, they sell it privately or locally as the auction provides low price.

Tea is exported to Taiwan, Ukraine, the United States, Japan, Germany, China, the European Union, Denmark, Poland, the Philippines, and many other countries

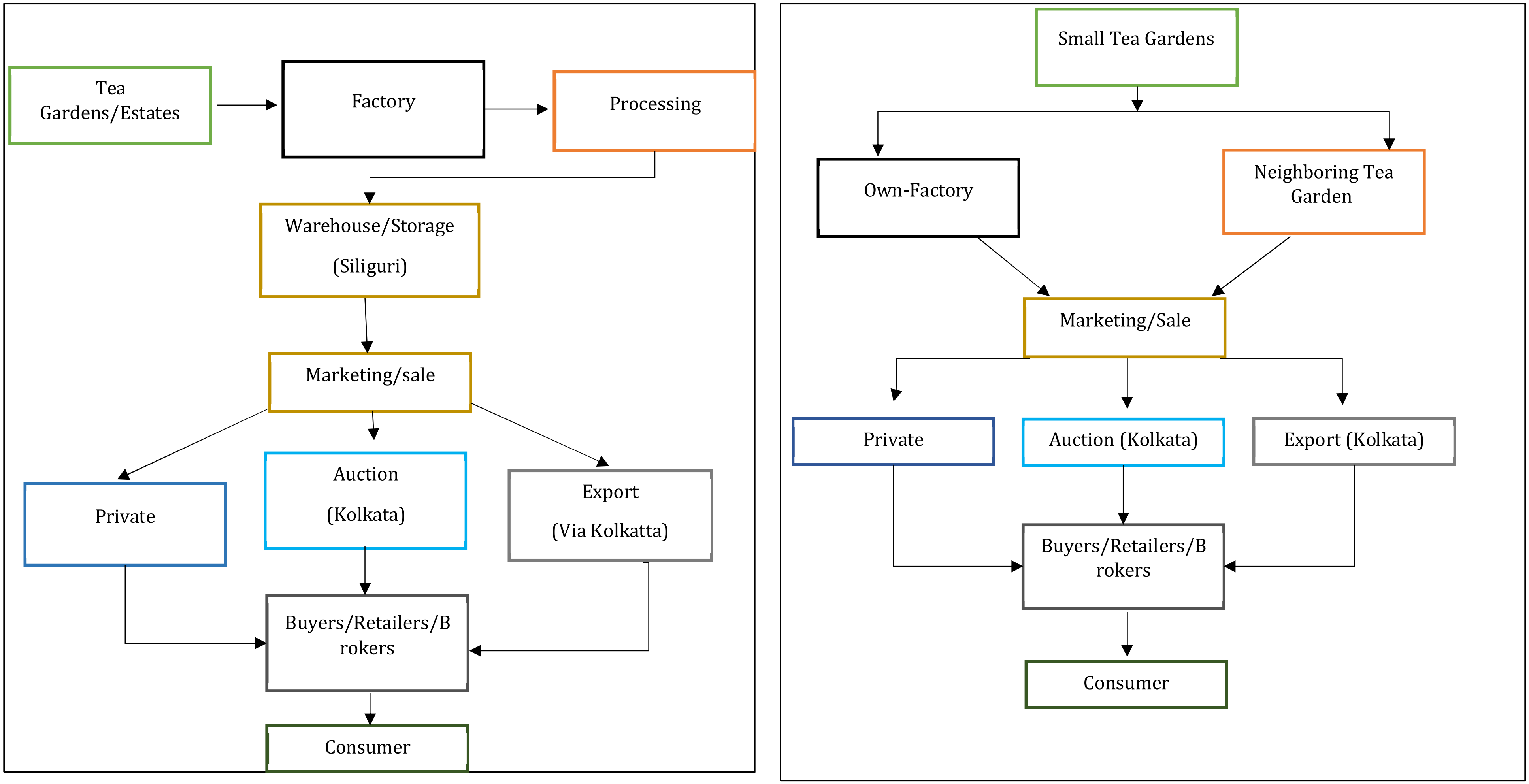

Figure 4: Marketing channels of Tea Gardens and STGs in Darjeeling Hills

Perspectives on Smallholder Gardens

A small tea garden is defined as having a plantation area of less than 25 acres by the Tea Board of India. However, in India, the tea sector has seen a tremendous increase in small tea growers (STGs) throughout the post-reform period as a result of the economic changes or liberalization of the economy that began in the 1990s. Presently in India, 210225 STGs occupy 215886.40 hectares and produce about 653.55 M.kg of tea (Hannan, 2021). Around 51 per cent of tea is produced in India owing to the STGs (Krishnakumar, 2022). Darjeeling hills has also witnessed the growth of STGs in the region since 1997 (Field Survey, 2022).

The main reason STGs are expanding so quickly is that established gardens have greater production costs than STGs do. Only two factors—plantation cost and factory cost or green leaf destination—are present in STGs. As a result, STGs are expanding quickly. Additionally, the established factories are cutting expenses by outsourcing their purchases of green leaves. As previously mentioned, the STGs filling the gaps and shortages contribute to the economy by boosting local and international demand.

Landuse and Resource Utilization

The STGs have a tea area ranging between 7- 18 acres. Out of the four sample STGs, two have their own factory. The production of tea depends on the other small growers who sell their green leaves to these factories. The green leaves are brought from neighbouring places like *Lamahatta,* and *Bara Pubung*. *Mirik*, *Chabesey*, *Pulungdung*, *Badamtam* etc.

All the STGs in the Darjeeling region are organised under societies like *Shelpu Tham Dara STGs Welfare society*; *Darjeeling Orthodox Small Tea Growers Welfare Society Organisation*; *Nim Small Tea Farmers' Producer Welfare Society* etc.

Working Conditions (Physical and Financial)

Employment in STGs is seasonal and during the off-season the labourers are unemployed. They work from 8 am- 4 pm daily. In estate gardens, labourers get all the facilities but they receive only wages in smallholder gardens. They have a day off on Sunday.

There are 15-20 daily (temporary) labourers working in STGs, many of whom are family members. They receive a daily wage ranging between Rs. 180-250 among these sample gardens and an additional Rs. 10 for every kg of additional leaves picked. The workers are not given access to any other amenities.

Marketing

The majority of the tea produced in STGs is sold to international countries like France, the United States, Germany, France, Russia, Australia, etc., and around 30 per cent is sold at auction (Fig. 4). In addition, the STGs in Darjeeling experience more issues with marketing as a result of their GI status than STGs in other states. They are unable to offer their products openly on the market. However, the GI designation has finally been approved and finalized for smallholders like Yaku and Nirola Farms after many years of hardship and still, there are many STGs without recognition. The only STGs in the region with their own factory are *Yanku Farms* and *Nirola Farms*.

Challenges and Opportunities of Darjeeling Tea

As mentioned by Managers during an interaction Darjeeling Tea is undergoing a deep crisis due to the rising cost of production followed by low price realization in national and international markets. It is reported that any price in an auction of fewer than 600 rupees per kilogram will lead to industrial sickness. Micro-Hydel Power Initiatives could be taken for reducing expenses and energy for tea processing. The rising cost may be due to old bushes and low productivity; the increase in input costs through labour wages is not at optimum levels. In the previous ten years, wage has increased by 15.77 per cent i.e., Rs. 90 in 2012 to Rs. 232 in 2022 (DTA), it barely meets the subsistence level. Thus, labour absenteeism is another challenge that the tea industry is facing as most of the labourers have out-migrated for better wages.

The tea is produced in the 87 tea gardens of Darjeeling hills which comes under the G.I indication and is in demand worldwide. The region produced 10 million kg of tea before 2010, according to Datta *et al.,* (2010), and according to ET Contributors (2021), output has decreased from 16 million kg thirty years ago to just 8 million kg in 2020. As per DTA (2019), production was 5565281 Kgs.

As per the data given production and yield (Table 4) in all the gardens were affected and yet to recover by the 104-day strike from June-September in the Darjeeling tea region which was mainly due to political unrest. Many gardens are sick and abandoned. Since that, all the buyers have moved to Nepal, Bangladesh, Sri Lanka, etc., which provide tea at cheaper rates as compared to Darjeeling tea (Ghosal, 2022). Darjeeling Tea is also facing a crisis from neighbouring Nepal tea which is openly sold in national and international markets as there is no import restriction between India and Nepal (Ministry of External Affairs, 2022). Hence, to fulfil the demand and gap, Nepal tea are combined with Darjeeling tea in Kolkata and sold as Darjeeling tea as per the field information.

The productivity is found to be more in terms of STGs due to its young tea bushes. Whereas the large estates have less productivity due to reasons like old age bushes. In terms of employment, the large tea gardens provide regular employment with various social security benefits to a large number of labourers as per the provision of the PLA, 1951. Collective bargaining and trade unions exist in the estate garden. But the STGs do not have such facilities other than wages. Employment in STGs is seasonal and leading to the increase of casualization of labourers. Thus, in the long run, the tea industry as a whole requires drastic refinement through research and policy upgradation and its application at the grass root level.

By encouraging the use of other services, such as tourism, through the implementation of public funding and development programmes and land diversification, the tea industry can be rejuvenated. The tea sector needs awareness, company optimism, and government backing in tea sales, in addition to fresh thinking and also a new mentality among the labourers. The Darjeeling tea sector would benefit if the government set minimum support prices, selling prices, minimum costs, and export prices as it does for other commodities as suggested by one of the managers. The bilateral tariff can be raised to stop tea imports from Nepal, digital initiatives and cluster marketing can be used to employ of young generation in the sector to avoid out-migration. Transparency in the tea sector and participation in decision-making should also be cultivated.

RECOMMENDATIONS AND CONCLUSION/S

India has a long history of tea cultivation and is one of the largest tea producers and consumers globally. The industry supports millions of direct and indirect jobs in the country. However, various challenges have affected the Indian tea industry, including a decline in exports, increased domestic demand, cheaper imports, market conditions, labour issues, aging tea bushes, competition from other countries and more. These factors have led to a crisis in the tea industry, including Darjeeling tea. The growth of STGs and their exclusion from labour protections further complicates the situation also it has led to the increase of labour casualisation. Addressing these issues requires concerted efforts to improve productivity, labour conditions, market presence, and sustainability in the industry.

Land Resources and Digital Interventions

Implementation of effective land utilization strategies through the use of space technology (e.g., Google Earth Platforms) and update the land resource mapping on regular basis. It would regular monitoring of gardens and recording data on canopy cover and identifying areas that require the replacement of old bushes. By utilizing space technology, accurate and up-to-date information on land use can be obtained, enabling efficient resource management.

Labour Management

Ensuring acceptable decent wages and fringe benefits to support a healthy living standard to the labouring community. This would enhance better human health and increase the labour productivity in the gardens and improve the quality of life of labourers. To achieve this, work schedules can be negotiated with the participation of labourers and adoption of new technologies, such as drones can be used spraying to combat insect and pest management in the gardens.

Capital Flow

Encouraging profitable gardens to reinvest by identifying new prospects for resource management within the local area. For instance, initiating micro hydel power projects that utilize river water resources to generate electricity can significantly reduce energy expenses in tea factories. Additionally, surplus hydroelectricity can be supplied to the national grid, benefitting the larger community. Gardens facing financial difficulties may require government support, and the Tea Board of India should conduct surveys and provide assistance to ensure the livelihoods of labourers in sick or closed tea gardens.

Technology Transfer

Recognizing the need for constant technological advancements in the tea industry, having the two sub-sectors namely estate and small gardens. Promoting collaboration with institutions such as the Tea Research Institute (TRA/UPASI) and agricultural research organizations, including KVKs, will facilitate the dissemination of new agricultural practices, tea processing techniques, and harvesting technologies. The adoption of these innovations will lead to cost reduction in production and increase overall efficiency in tea gardens.

Institutions & Governance

Tea industry is prevalent across the 15 provincial states and backward districts of India. Strengthening the tea industry's connection with local-level institutions, specifically the Panchayati Raj Institutions (PRIs), and implementing a bottom-up approach of governance will ensure effective coordination and decision-making processes. Involving PRIs, the government can facilitate better management and address local concerns related to the tea industry.

Tea Marketing

International Trade Fairs, identifying new destinations of tea exports, cluster marketing for domestic market through online marketing etc. to be supported by Tea Board of India to augment the contemporary crisis of Tea Industry.

Limitations and Acknowledgement

The current study is a part of ongoing research and temporal data from diverse institutional sources needs to be explored.

The authors are really grateful to everyone who helped with this study paper. We are appreciative to all the tea estate managers, garden staff, STGs owners, DTA members, trade unions, etc. for sharing their valuable knowledge and information during field survey. The current research would not have been possible without their help.

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PRESENT STATUS OF 'C' SEQUESTRATION IN COCOA PLANTATIONS

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ABSTRACT

The total area under agroforestry in the world is estimated at around 1 billion ha. The cocoa crop is cultivated in agroforestry systems together with many tree species and other crop plants on the same plot. Carbon stocks in shaded agroforestry systems with perennial crops—such as coffee, rubber, and cocoa—may vary between 12 and 228 Mg ha^{-1} and could help to mitigate climate change. The contribution of cocoa for sustainable production and the provision of ecosystem services (including carbon sequestration to abate climate change) at the landscape level has been explored in terms of the dichotomy between promoting intensive cocoa production to free natural forest areas for pure conservation (land-sparing strategy) and promoting mixed, environmentally friendly cocoa agroforestry systems, which may require a larger area due to smaller yields (wildlife-friendly farming strategy) but could reduce deforestation. The disease Cherelle wilt of cocoa can be reduced as it is grown under the shade of forest trees which reduced the input cost and input of agrochemicals into the ecosystem. The inputs like biochar, fertilizers, and composted organic manures may be added to increase carbon sequestration.

Keywords: Agroforestry**,** Carbon sequestration, Climate change, Cocoa

INTRODUCTION

Carbon sequestration is the process of capture and long-term storage of atmospheric CO_2 or forms of carbon to either mitigate or defer global warming and reduce the effect of dangerous climate change. CO_2 is naturally captured from the atmosphere through physical, chemical, and biological processes. During growth, all crops absorb CO_2 through photosynthesis and release it after harvest due to decomposition. The goal of carbon removal in agriculture is to utilize the crop residues and products such that the carbon cycle sequesters carbon permanently within the soil system by adopting farming methods to return biomass carbon to the soil and stored it in a stable state. Stern (2006) notes that deforestation alone is responsible for 18 % of the world's greenhouse gas emissions.

One option to reduce deforestation and create a carbon sink is to encourage the establishment of tree-crop farming or agroforestry systems (UNFCC, 2009; Oke *et al.,* 2011; Askia *et al.,* 2016) in the existing plantations.

MATERIALS AND METHODS

A review of the present status of C sequestration in the cocoa plantation was done with the objective to study the status of cocoa plantations in India and the world, carbon sequestration and its potential; towards climate change, Cocoa plantation and its carbon sequestration potential (review of research and reports published on cocoa), Management practices and input addition for cocoa plantation in relation with their effect on carbon sequestration, *etc.* through published sources.

Status of cocoa plantations in India or the world

The total area under agroforestry in the world is estimated at around 1 billion ha. The cocoa crop is cultivated in agroforestry systems together with many tree species and other crop plants on the same plot.

Carbon sequestration and its potential for the climate change

Methods for accomplishing carbon sequestration include mulching the soil with hay or dead vegetation. This protects soil from the sun and allows the soil to hold more water and be more attractive to carbon-capturing plants. On degraded wastelands, an increase in 1 tonne of soil carbon will increase the crop yield by 20 to 40 kg ha^{-1} of wheat, 10 to 20 kg ha^{-1} of maize, and 0.5 to 1 kg ha^{-1} of cowpeas

Cocoa plantation and its carbon sequestration potential (review of research and reports published on cocoa)

Cocoa-based agroforestry systems have the potential for stocking huge amounts of carbon to mitigate climate change. Carbon stocks in shaded agroforestry systems with perennial crops—such as coffee, rubber, and cocoa—may vary between 12 and 228 Mg ha^{-1} and could help to mitigate climate change (Nair *et al*., 2009). In Central America, 24,000 ha of cocoa are grown without inorganic inputs or pesticides, plantations are small (0.25–3.0 ha) with high plant species richness and structural complexity, product diversification for own use, sale, maintenance of permanent soil cover, and organic matter. These will promote soil and water conservation.

The following table (Table 1) explains that cocoa could be an ideal intercrop in an oil palm- cocoa-based cropping system as it could sequester more carbon than sole oil palm crop (Bhagya and Suresh, 2018)

Table 1: Effect of cocoa cropping systems on C sequestration

Cropping system	Standing biomass (t ha^{-1})	Carbon stock (t ha^{-1})	Carbon sequestration (t ha^{-1})
Cocoa	95	48	175
Oil palm	60	30	110
Oil Palm with Cocoa	155	78	284

Total biomass C stocks (above- and belowground) increased fivefold from the monoculture to the multi-shade tree system (from 11 to 57 Mg ha^{-1}), and total net primary production rose twofold (from 9 to 18 Mg C ha^{-1} yr^{-1}). This increase was associated with a 6fold increase in aboveground biomass, but only a 3.5fold increase in root biomass, indicating a clear shift in C allocation to aboveground tree organs with increasing shade for both cacao and shade trees (Table 2). Despite a canopy cover increase from 50 to 93%, cacao bean yield remained invariant across the systems (variation: 1.1–1.2 Mg C ha^{-1} yr^{-1}). The monocultures had a twice as rapid leaf turnover suggesting that shading reduces the exposure of cacao to atmospheric drought, probably resulting in greater leaf longevity.

In contrary to general belief, cacao bean yield does not necessarily decrease under shading which seems to reduce physical stress (Abou Rajab *et al.,* 2016). If planned properly, cacao plantations under a shade tree cover allow combining high yield with benefits for carbon sequestration and storage, production system stability under stress, and higher levels of animal and plant diversity. (Abou Rajab *et al.,* 2016)

Table 2. Effect of cocoa cultivation methods on net primary production and litter production

Cultivation system	Carbon net primary production (t ha^{-1} year^{-1})			Litter production (t ha^{-1} year^{-1})			
	Cacao	Shade trees	Total	Leaves of cacao	Leaves of shade tree	Other litter components	Total
Cacao mono	8	-	8	4.5	-	0.2	4.7
Cacao mono Gliricidia	12	2	14	2.5	1.5	0.2	4.2
Cocoa multi shade trees	7	9	16	2.4	5.5	1.5	9.4

The contribution of cocoa for sustainable production and the provision of ecosystem services (including carbon sequestration to abate climate change) at the landscape level has been explored in terms of the dichotomy between promoting intensive cocoa production to free natural forest areas for pure conservation (land-sparing strategy) and promoting mixed, environmentally friendly cocoa agroforestry systems, which may require a larger area due to smaller yields (wildlife-friendly farming strategy) but could reduce deforestation (Tscharntke *et al*., 2011). To reduce deforestation and loss of natural forests, it is proposed to transform rustic cocoa into cocoa with productive shade (e.g. cocoa–timber systems), a controlled intensification that would nonetheless reduce biodiversity and ecological complexity. In Bahia, Brazil, a large cocoa-growing territory encompassing more than 500,000 ha of rustic cocoa (a wildlife-friendly landscape) and a few remnants of protected mature forest, intensive mono cultivation is not recommended because it will affect natural forest (Gockowski and Sonwa, 2011)

Management practices and input addition for cocoa plantations in relation to their effect on carbon sequestration

Cocoa planted under the shade with wider spacing (less density) stores more carbon per unit area of soil than planting cocoa at less spacing (high density) without shade. Conversion of natural forest to agricultural land with cocoa planted at high density (1667 trees ha^{-1}) resulted in the historic depletion of soil organic carbon but there were gains of soil organic carbon with cocoa at lower plant density (1,111 trees ha^{-1}). Cocoa Research Institute of Ghana (CRIG) recommended that cocoa should be planted under some shade trees preferably 16 to 18 trees ha^{-1} and at the planting density of 1,111 cocoa trees ha^{-1} to increase carbon accumulation in soils as a way of reducing carbon dioxide emissions into the atmosphere.

Under shaded farms, litter fall is slightly reduced but the rates of decomposition of leaf litter are very slow compared to the shaded farms. Higher N and P are noticed in soils under shade than in open farms because of the efficient nutrient cycling process in shade farms. A higher incidence of Cherelle wilt was noticed in un-shaded farms. This is due to increased moisture stress because of increased evapotranspiration in mono-cultivated farms (lack of shade) and reduced nutrient concentration in the soils due to lack of nutrient cycling to support the resistance to crop. Finally reduces crop yield in mono cultivation (Table 3). Growing cocoa plants under shade enhances better nutrient cycling, improved the fertility status of soil and disease-free pod development.

Table 3. Effect of different cocoa systems on number of healthy cocoa pod

No.	Particulars	Number of healthy pods
1	Monoculture (control)	8
2	As Inter crop (heavy shade)	17
3	As Inter crop (Under medium shade)	19

Tree diversity for shading cocoa plantations is recommended in cocoa farming to for climate change adoption. The manipulation of the morphological and functional traits of canopy species has been used to optimize shade canopy design and could be used in cocoa to both maintain high yields and carbon stocks. To store more carbon without sacrificing cocoa yields, selection of tree species with (1) tall, cylindrical, and thick stems—a tree form that may be called Sequoia—like *Terminalia ivorensis* in West African cocoa plantations. Large trees store most of forest aboveground biomass; tall trees cast a “lighter” shade than short trees;(2) small canopies and light foliage (like *Albizia spp*.; (3) large, deep, thick roots; and (4) rapid growth and high-density timber; (5) inverted phenology which would be of special interest (e.g. *Faidherbia albida* in Africa, which loses foliage during the rainy season and keeps it during the dry season). This inverted phenology behavior has been observed in *Dalbergia glomerata* (a highly valuable timber) used as shade over cocoa in Honduras. It seems possible to design cocoa plantations with high carbon stock levels and good cocoa yields.

Organic manures can be applied along with inorganic fertilizers to enhance growth and yield thereby increasing carbon sequestration. The organic manures (poultry manure and green manure) were applied at the rate of 0.56 tonnes/ha (500 g/seedling); urea and single superphosphate were applied at rates of 0.26 and 0.11 tonnes/ha, respectively.

Cocoa, 80 per cent of which is cultivated by smallholders, is an export crop for many countries in Africa, and black pod disease caused by *Phytophthora spp*. is a major constraint to its production. Cocoa pod husk has been identified as a major source of inoculums of *P. megakarya* if left in farmers' fields as waste. Cocoa pod husk may be dried and burned in limited oxygen in a kiln to produce biochar. Biochar can be used as an alternative to control black pod disease and improve cocoa yields in smallholder farms while reducing farmers’ spending on chemicals for black pod disease.

In the Toledo district of Belize, cocoa trees are prone to the fungal disease monilia, made worse by lack of airflow through the orchards. This creates huge waste that is generally burnt resulting in emissions of atmospheric CO_2. This pruning provides a sustainable source of feedstock for producing biochar. Crop fertilization in the form of biochar improves soil fertility, promotes plant growth and resistance to biotic stresses, and helps to mitigate climate change (One tonne of biochar is equivalent to 2.7 tonnes of CO_2 removed from the atmosphere). In addition to this, they are raising grafted plants in nurseries, often for up to eight months before they are planted out in an orchard setting. Grafting allows for stronger rootstock to be spliced onto a superior fruiting stem – thereby increasing plant strength and yield. This means that young plants are subjected to a long period in a nursery environment, sometimes throughout the entire dry season when irrigation can be sporadic. As biochar has water retention properties, its advantages to this new, nursery-based growing system.

Biochar was mixed with locally sourced nutrients and applied to the soil around the base of semi-mature and mature trees, around the drip line, and under the leaf litter. Within twelve months, growers reported benefits to cocoa trees including more vigorous growth, improved flushing (Cocoa trees exhibit a flushing-type growth habit, with two to four growth flushes per year), boosted disease resilience, increased yield, and earlier maturation time

Cacao farming when carried out as part of an agroforestry system with over 25% shade trees has great potential to act as a carbon sink and can sequester about 30 kg CO_2 eq. per kg of dry bean (Alluri *et al.,* 2022).

The incentives to emit less and capture more greenhouse gases, such as the Joint Implementation and Clean Development Mechanisms, REDD+ (Reduced Emissions from Deforestation and Forest Degradation), and voluntary carbon markets (Christina, 2010) extended to the farmers through complete documentation of carbon sequestration. The farmers can get extra benefits for increasing carbon stock without sacrificing regular income through cocoa cultivation by the adoption of a cocoa-based agroforestry system instead of monoculture, application of green manure, compost, and biochar may boost the yield of cocoa by increasing carbon sequestration.

RECOMMENDATIONS AND CONCLUSION/S

In conclusion, it is important to consider multiple factors when evaluating the impact of shading on cacao bean production. While there may be a common belief that shading reduces yields, it is not necessarily the case. Shading can provide a favorable environment that reduces physical stress on the plants, potentially leading to maintained or even increased yield levels. However, it is crucial to broaden the scope beyond yield alone. Shading has the potential to contribute significantly to carbon capture, which plays a vital role in mitigating climate change. The amount of carbon captured can serve as an additional metric to assess the overall sustainability and environmental impact of cacao bean cultivation under shading. Furthermore, the economic aspect cannot be overlooked. The price paid for carbon capture can provide financial incentives for farmers to adopt shading practices, which in turn promotes sustainable agricultural practices. By incorporating shading methods that enhance carbon sequestration, farmers can potentially participate in carbon offset programs and receive monetary compensation for their contribution to climate change mitigation.

In summary, while shading may not necessarily decrease cacao bean yields, it offers additional benefits such as carbon capture and potential economic advantages. By recognizing the holistic impact of shading on production, carbon sequestration, and financial incentives, we can foster a more sustainable and environmentally conscious approach to cacao bean cultivation.

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Technical Session III

“Technological Innovations”

Lead Presentation Delivered by;

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DEVELOPMENT OF READY TO SERVE NUTRITIONAL PORRIDGE BASED ON DEFATTED COCONUT MILK AND RICE

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ABSTRACT

The Defatted Desiccated Coconut Residue (DDCR), which is obtained following the extraction of virgin coconut-oil or milk, with proven nutritional benefits, is often underutilized. The DDCR's water extract (skim milk) has the potential to be incorporated into the food industry through the creation of value-added products. Moreover, the defatted coconut milk (skim milk) obtained from DDCR can be used in low-fat liquid diets. Accordingly, the present study was designed to develop a ready to serve nutritional porridge incorporating skim milk with rice at different ratios and to evaluate its proximate composition, sensory properties and storage stability. In this study, a series of porridge samples were prepared in varying proportions of skim milk and rice (T1: Skim milk 75%, Rice paste 25%, T2: Skim milk 50%, Rice paste 50%, T3: Skim milk 25%, Rice paste 75%). The outcomes of the study revealed that protein contents of both T1 and T2 were significantly higher than that of T3. The highest fat content was observed in T1 while both T1 and T3 showed higher fibre content compared to that of T2. Moreover, carbohydrate content and energy value were also lesser in T1. However, no significant difference was observed according to the results of sensory evaluation on the appearance, aroma, color and mouth feel ($p< 0.05$). Yet, the taste and overall acceptability value were significantly higher in Treatment 1 (Skim milk-75%, Rice paste-25%) compared to those of other two treatments. The pH values of three treatments showed a significant difference between samples and pH value of each treatment gradually decreased with increasing storage period. In each treatment, microbial growth remained within safety margins until first week. However, a significant increase in total plate count and yeast and mold count was observed after 2 weeks of storage time. Accordingly, the recommended storage period of the product was determined as one week. Based on the sensory and proximate results, the formulation in the Treatment 1 (Skim milk 75%, Rice paste 25%) was selected as an improved nutritional porridge for the children, youngsters and adults to fulfill their dietary requirements.

Keywords: Microbial evaluation, Porridge, Sensory evaluation, Shelf-life Skim milk

INTRODUCTION

At present, the utilisation of food by-products and wastes receives more attention in the food industry. These wastes and by-products can be sustainably utilized by integrating into the food industry during food processing for value-added product development. Defatted Desiccated Coconut Residue (DDCR) is one of the major by – products generated from the virgin coconut oil (VCO) industry. This defatted coconut residue is often underutilized. However, this whitish residue can be milled into flour which is more nutritious and healthier source of dietary fibre (Trinidad *et al.*, 2003). The utilization of this valuable resource has been extensively studied over the last years (N.Sujirtha, 2015). Coconut Skim Milk (CSM) is another potential by product obtained from DDCR. Coconut milk with a fat content of less than 3.75% is classified as "skim coconut milk" by the Codex Standard for aqueous coconut products (Khuenpet *et al.*, 2016). Water is added to DDCR in 1:1 ratio followed by hydraulic press resulted in CSM. However, CSM is a rich source of carbohydrate, proteins, minerals and fibres (Naik *et al.*, 2014). Presently, the majority of the global population is suffering from non-communicable diseases such as diabetes, coronary heart attacks and high blood pressure (Ma & Lee, 2016). It has been proven over the years that the consumption of high fat diets has been the main cause for increasing these disease levels (Scherer & Hill, 2016). Therefore, CSM diets can be introduced as an ideal alternative to low fat diets to cope with the modern - day health issues (Agdeppa & Zamora, 2022).

Further, when we consider the food habits of Asian countries, most of them consume rice as one of their staples. Rice is a good source of complex carbohydrates, which is an important source of energy (Malyala & Aparna, 2019). At present, ensuring food security has become a global challenge. Therefore, changing consumption patterns, sustainable resource utilization and value-added product development are crucial factors to be considered in ensuring the food security of a nation.

The oil cake or DDCR generated during the coconut oil extraction process are in most cases utilized as a source of animal feeds (Pipatpaitoon & Paraksa, 2021),(Erasmus & Overwater, 2010), (Adeloye *et al.*, 2020) . However, it has been proved that the residue of virgin coconut oil production is a rich source of nutrients that is suitable for human consumption (Naik *et al.*, 2014), (N.Sujirtha, 2015). Yet, still it is underutilized and studies based on the value-added product development using the residue of virgin coconut oil production are very limited. Accordingly, the present study aims to develop ready-to-serve nutritional porridge by utilizing coconut skim milk and rice as an alternative source of meal. Hence, it will pave the way for fulfilling the nutritional requirements of a nation while ensuring the food security and sustainability of the country.

MATERIALS AND METHODS

Study area

The study was conducted at the Coconut Processing Research Division, Coconut Research Institute, Lunuwila, Sri Lanka.

Materials

DDCR were taken from the Coconut Processing Research Division, Coconut Research Institute, Lunuwila, Sri Lanka. White raw rice, sugar, and common salt were purchased from retail market in Madampe, Puttalam district, Sri Lanka.

Preparation of Skim milk

The skim milk was made from coconut residue remained after extracting VCO. The residue was soaked in hot water and broken in to small particles by hand. The ratio of DDCR to water was maintained as 1:1 (w/w) and the soaking time was 1 hour. Then, the skim milk was extracted from DDCR using the hydraulic press machine.

Preparation of rice paste

White raw rice was cleaned and soaked in water for 4 hours. Then well soaked rice was blended until it reached to a homogeneous thick paste. Then homogeneous rice mixture was mixed with water to the ratio of 1:5 (w/w).

Product formulation

The skim milk and rice paste were mixed in specific ratios and heated until it reached to 80^0 C with continuous stirring. Sugar and salt were added in specific amount while heating the mixture (Table 1). Then porridge mixture was allowed to cool to the room temperature (25 ^{0}C) and packed in polystyrene cups and sealed.

Table 1: Formulation of porridge samples

Ingredients	Treatment 01 (T1)	Treatment 02 (T2)	Treatment 03 (T3)
Skim Milk	75%	50%	25%
Rice Paste	25%	50%	75%
Sugar	5.5%	5.5%	5.5%
Salt	0.5%	0.5%	0.5%

The three porridge samples were analysed for physicochemical properties. After, sensory evaluation of the prepared porridge samples was carried out.

Determination of proximate composition of porridge samples

Moisture, Fat, Fiber, Ash, Protein contents were determined using the standard methods as per the (AOAC. 2005).

Determination of moisture content

An empty petri dish was dried in the oven at 103^0 C for 2 hours before being placed in the desiccator to cool. The empty petri dish was weighed and 5g of the sample was added and allowed to oven dry for 3 hours at 103 ^{0}C. Then the dish with the sample was placed in the desiccator to cool after drying. Weight of the oven dried sample was recorded. Then the moisture content of the sample was measured repeatedly in 1hour intervals until a constant weight was obtained.

Equation 1:

$Moisture$ (%) = ($W_1 - W_2$ /sample weight) × 100

W1= Empty petri dish + Sample weight (g)
W_2 = Final oven dried weight (g)

Determination of fat content

Empty fat beakers were dried in the oven at 103 ^{0}C temperature for 2 hours. Then, the beakers were transferred to a desiccator to cool before being weighed. Dehydrated porridge samples were put into thimbles (fresh weight 5g) and set the thimbles in fat extractor. After that, 75ml of petroleum ether was poured into fat beakers. Thimbles and beakers were correctly placed in a fat extractor and instrument was heated at 100 ^{0}C for about 4 hours. Then set the valve of the equipment at horizontal position until all ether was removed (15min). Finally, fat beakers were kept in the oven at 103 ^{0}C temperature for 2 hours and the final weight was recorded.

Equation 2:

FC = ((FW-EW)/ (WS)) × 100

FC = Fat content of the sample (% w/w)
FW= Final weight of the respective beaker with the sample (g)
EW= Empty weight of the beaker (g)
WS = Weight of the sample (g)

Determination of crude fiber

Empty gooch crucibles were placed in a muffle furnace at 550 ^{0}C for 2 hours. Sample solutions of 1.25% H_2SO_4 and 1.25% KOH were prepared separately while distilled water was taken into a 2L beaker. Then, those three reagents were heated using a hot plate. Moisture and fat free samples were put into the gooch crucible and set it in fiber extractor. H_2SO_4 solution (1.25%) was added to each sample and set the timer for 30min. After 30 min, samples were washed using heated distilled water for three times. Thereafter, KOH

(1.25%) was added into the tube and again set the timer for 30 min. After that, samples were washed again using hot distilled water for three times and finally washed with acetone (purity level: 99.8%). Then crucibles with contents were transferred and oven dried at 103 ^{0}C for 2 hours and transferred in to a desiccator. The weight of crucible containing crude fiber was measured (W_1). Then crucibles were placed in a muffle furnace at 550 ^{0}C for 3 hours and the final weight was taken (W_2) after cooling.

Equation 3:

Crude Fibre = $(W_1-W_2)/ (SW) \times 100$

W_1= Final oven dried weight (g)
W_2= Final weight after keeping in the muffle furnace (g)
SW= Weight of the sample (g)

Determination of Ash content

Empty crucibles were placed in a muffle furnace at 550 ^{0}C for 2 hours and transferred to a desiccator to cool. Then empty weights of crucibles were recorded. Then, 5g of food sample was weighed into a crucible and the content was evenly distributed. Thereafter, crucibles were placed in the muffle furnace at 550 ^{0}C for 6 hours. Again, crucibles were transferred to the desiccator and weights of crucibles with ash were measured.

Equation 4:

Ash content (%) = $((W_2 – W_1) / SW) \times 100$

W_2 = Weight of the crucible 6 hours after burning in the muffle furnace (g)
W_1 = Empty weight of the crucible (g)
SW = Weight of the sample (g)

Determination of crude protein

The kjeldahl method was used to determine the crude protein content. First, 0.25g of the sample (moisture removed and defatted sample) was added into the digestion flask. Then, 25ml of conc. H_2SO_4 and digestion catalyst were added into the digestion flask. Thereafter, the flask was kept at 150 ^{0}C for 10 min and 400 ^{0}C for 150 min (until a clear solution was appeared). Then, the digested sample was transferred into a volumetric flask and the final volume was adjusted to 100ml using distilled water. For the distillation process, a protein distillation unit was used. A volume of 25 mL of the digest was placed in the tube of the distillation unit. The distillation process was continued until the red color of the boric acid turned into green color. Then the conical flask with the boric acid solution was titrated 0.1 M HCL until green color turns pink.

Equation 5:

$$N\% = \frac{N_{HCl} \times \text{titration volume} \times \text{sample volume} \times 14.007}{1000 \times \text{sample used} \times \text{sample weight}} \times 100$$

$$\text{Protein} = N\% \times 6.25$$

Determination of total carbohydrate content

Carbohydrate content was determined by the difference (100 — [sum of moisture, ash, fat and protein contents]). Moreover, energy conversion factor was used to estimate the energy values (% carbohydrate + % protein +% fat) in kcal/100 g (FAO, 2003) .

Sensory evaluation of porridge samples

The 5-point hedonic scale was used for the sensory evaluation of samples. Samples were given to 30 untrained panelists and instructed them to evaluate samples for appearance, color, aroma, mouth feel, taste and overall acceptability of the samples.

Determination of pH

The pH of the porridge samples was determined using a pH meter (Bench Top Professional pH Meter HI 2020).

Determination of Microbial count

The storage stability of porridge samples was determined by microbial count (Total plate count method-ISO 4833-1: 2013, and yeast and mould count method – ISO 21527-2: 2013). All the glass wares were sterilized at 175 ^{0}C for 1 hour (SLS 516: part 1: 1991). 1ml of sample and 9 ml of sterilized water were added and mixed well using stomacher blender. Then dilution series was prepared as 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4} and 10^{-5}.

Media preparation was done by using standard method (ISO 4833: 2013). Nutrient agar medium for total plate count and potato dextrose agar medium for yeast and mould were prepared and kept in the autoclave. Then 1 ml of aliquots from 10^{-1}, 10^{-2}, 10^{-3}, 10^{-4} and 10^{-5} dilution series were transferred into pre-sterilized petri dishes. 15-20 ml of prepared medium was poured into each petri dish. It was rotated for even distribution and allowed to solidify. Then, the inoculated nutrient agar plates and potato dextrose agar plates were incubated at 37 ^{0}C for 24 hours.

Statistical analysis

Proximate results were analysed by one-way ANOVA followed by Tukey's post hoc test at 5% significant level using SPSS software package (version 25). Sensory data were analysed using Friedman non-parametric statistical test in SPSS. Descriptive analysis was carried out using Microsoft excel software package.

RESULTS AND DISCUSSION

Proximate composition of ready to serve porridge samples produced from skim milk and rice

The results of proximate composition of porridge samples are shown in Table 2. Among three treatments, significant differences ($p \leq 0.05$) were observed for moisture, fat, fiber, ash, protein. The moisture content of ready to serve porridge ranged from 72.48% to 78.69%, with significant differences among the treatments.

Porridge is somewhat moist food and moisture plays a significant role in achieving the proper consistency of the porridge. The highest moisture content was reported in T3 (78.69%) while significantly lower moisture content was recorded in T1 (72.48). However, in the present study, the moisture content of the porridge samples was increased significantly with increasing percentage of rice paste. This was possibly due to the higher dilution of the rice paste when preparing the paste (1:5). High moisture food products typically have a shorter shelf life stability (Adebowale & Komolafe, 2018).

It has been reported that a low fat diet reduces the obesity and mortality associated with cardio metabolic disease (Gitau *et al.*, 2019), (Billingsley *et al.*, 2018). The fat content of the defatted coconut residue is about 17.26% (Mohd Nor *et al.*, 2017). However, the fat contents of the porridge samples prepared ranged between 0.41 to 0.04 %. Due to higher dilution of the skim milk during the porridge preparation process, fat content has been reduced further.

Crude fiber is a type of carbohydrate that our bodies cannot digest. After digestion, insoluble fiber acts as a broom to sweep out the digestive tract, preventing constipation, gut infections, hemorrhoids, heart disease, and some types of cancer. As a result, eating fiber rich foods is of an importance in living a healthy life (Pathirana *et al.*, 2020). The lowest crude fibre content was observed in T1 and that was 3.13% (75:25% Skim milk and Rice paste) and the highest crude fibre content was observed in T3 and that was 5.13% (25%, 75% - Skim milk and Rice paste, respectively). Therefore, it suggests that with the increasing content of rice paste in porridge samples, the crude fibre percentage has also increased.

The ash content of food provides an overview of its mineral content. Mineral fortification of food products is a novel trend for increasing nutrient content while gaining nutritional benefits for human life (Pathirana *et al.*, 2020). The ash contents of samples were slightly raised with the increase of skim milk content. The range of the ash content was 3.64 to 0.53%. The T1 sample (Skim milk-75%, Rice paste 25%) showed the highest ash value while T3 sample (Skim milk- 25%, Rice paste 75%) showed the lowest. Results suggest that the defatted coconut has a high ash content than that of rice. As a result, the defatted coconut milk increased the quantity of mineral in a food product (Adebowale & Komolafe, 2018).

Proteins are essential macromolecules required for the development of biological organs. The results in Table 02 indicates that the increase in the percentage of defatted coconut milk in the sample has contributed for an increase in crude protein in the porridge mixture**.** The protein content of porridge sample has been increased because of the higher protein content (12.6%) of the defatted coconut flours (N.Sujirtha, 2015). The T1 (75% skim milk) and T2 (50:50%) porridge samples had higher protein content of 6.94% and 5.91%. However, lower protein content of 2.13% was observed in treatment 3 (25% Skim milk, 75% Rice paste). It has been reported that cereal protein is limited with the essential amino acid, lysine, and hence, the biological value of cereal flour can be significantly improved by the addition of lysine through skim milk (Sousa *et al*., 2020). Therefore, coconut skim milk when incorporated into rice increases the amino acid content, especially lysine. Therefore, the incorporation of coconut milk into rice improves the protein quality and thus improves the nutritional status of the end product.

Table 2: Proximate composition of porridge samples

Treatment	Moisture	Fat	Fibre	Ash	Protein	Carbohydrate	Energy
T1T2T3	72.48 ± 0.17^{c} 75.62 ± 0.00^{b} 78.69 ± 0.11^{a}	0.41 ± 0.01^{a} 0.16 ± 0.00^{b} 0.04 ± 0.00^{c}	3.13 ± 0.32^{b} 5.11 ± 0.00^{a} 5.13 ± 0.00^{b}	3.64 ± 0.03^{a} 1.67 ± 0.05^{b} 0.53 ± 0.11^{c}	6.94 ± 0.41^{a} 5.91 ± 0.45^{a} 2.13 ± 0.12^{b}	16.54 ± 0.36^{b} 16.62 ± 0.48^{b} 18.61 ± 0.56^{a}	97.55 ± 0.14^{a} 91.63 ± 0.21^{b} 83.29 ± 0.44^{c}
F value	63561.36	1057.00	109.80	413.18	49.40	11.34	586.96
P value	0.0001	0.0001	0.0001	0.0001	0.0001	0.009	0.0001

Carbohydrate Content and Energy value of Ready-to-serve nutritional porridges

The carbohydrate content of the porridge samples varied from 18.61% to 16.62% (Table 2). The T3 was having the highest amount of carbohydrate (18.61%) compared to those of other samples owing to the high proportion of rice paste (Rice paste-75%, Skim milk-25%). Rice contributed greatly to high carbohydrate content (Padma *et al*., 2019). The T1 (skim milk (75%) and T2 (50:50%) having lowest carbohydrate content of 16.65% and 16.62%. Defatted coconut residues contain low carbohydrate content (25.73%) (McClements, 2015).

The energy contents of porridge samples increased as the amount of skim milk added increased. The value ranged from 97.55 to 83.29 kcal/100 g. Accordingly, T1 (Rice paste-25%, Skim milk-75%) had the highest energy value (97.55 kcal/100 g) and 83.29 kcal/100 g was the least value for T3 (Rice paste-75%, skim milk-25%).

Table 3: Mean sensory ratings obtained for the multiple comparison of porridge samples

Trial number	Attributes					
	Appearance	Colour	Aroma	Mouth feel	Taste	Overall Acceptance
T1	4.06±0.76[a]	3.73±0.78[a]	3.66±0.76[a]	3.96±1.03[a]	4.46±0.73[a]	4.16±0.65[a]
T2	3.90±0.96[a]	3.96±0.85[a]	3.96±1.25[a]	4.10±0.48[a]	3.70±0.74[b]	3.90±0.66[b]
T3	4.03±0.81[a]	4.13±-.93[a]	3.70±0.79[a]	3.76±0.97[a]	3.73±0.87[b]	3.66±0.71[b]
P value	0.571	0.121	0.242	0.557	0.0001	0.002

The results of the mean sensory ratings obtained for the multiple comparison test are presented in (Table 3). There were no significant differences ($p<0.05$) among the three treatments with respect to the appearance, colour, flavour, and mouth feel. However, when the attribute taste is considered, T1 differed significantly from other two treatments. Even though, there were no significant differences between treatments with respect to most attributes tested, based on the taste, most panelists have selected the formulation in the T1 with higher overall acceptance which varied significantly from the rest of the treatments. In addition to, Fig. 1 shows taste and overall acceptability, T1 can be selected as the best treatment out of the three, considering the higher mean scores for colour, flavour, and mouth feel.

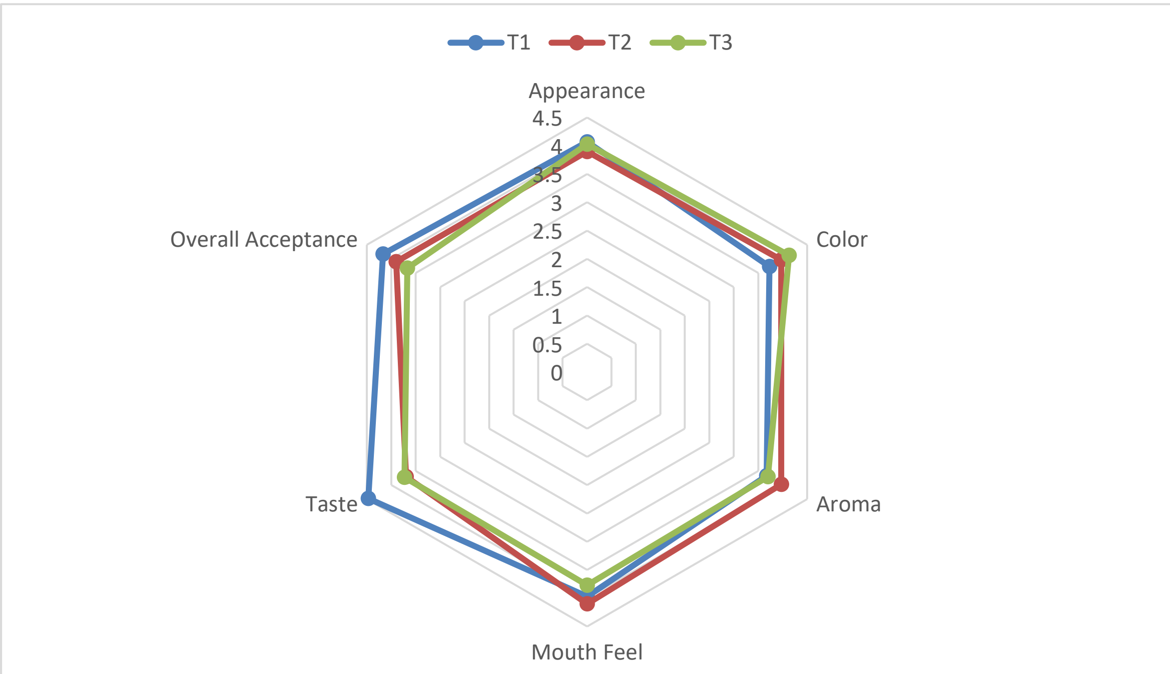

Figure 1: Sensory attributes and overall acceptability of ready to serve breakfast porridge based on defatted coconut milk and rice (T1= Skim milk-75%, Rice paste-25%, T2= Skim milk-50%, Rice paste-50%, T3= Skim milk-25%, Rice paste-75%).

Determination of pH value

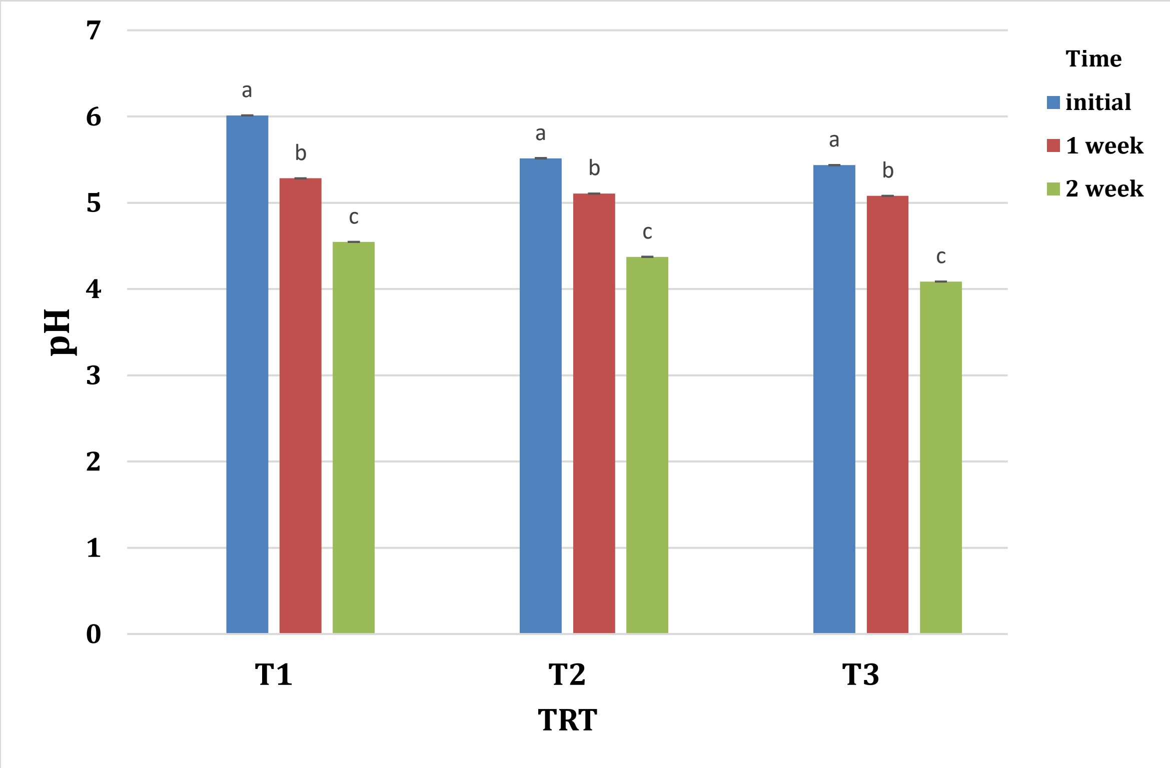

Figure 2: Determination of pH value of porridge samples within storage period. Superscript letters above the columns indicate significant different among each treatment.

The Fig. 2 shows the results of the determination of pH value. The pH is a measure of the concentration of the free hydrogen ions in the samples. The pH values of three treatments differed significantly. The highest pH value was observed in initial stage (T1- 6.01, T2- 5.51 and T3- 5.44) and the lowest value was observed after 2nd week (T1- 4.55, T2- 4.37 and T3- 4.08). When the cooling condition is increased, the acidity of the coconut residue rises. However, at pH 6.9 approximately 0.6% lactic acid can be produced and at pH 5.0 approximately 0.9% lactic acid can be produced. Lactic and acetic acids were formed when anaerobic bacteria broke down the carbohydrates in coconut milk, increasing the acidity and lowering the pH level. Other studies have shown that the samples with more pronounced lipid and protein degradation would allow for the release of free fatty acids (Sheikh *et al*., 2020). This may also cause decreasing the pH of the product with the storage period (Hanafi *et al.,* 2022).

Analysis of microbial content during storage period under Refrigerator temperature (4°C)

The Total plate count and yeast and mold count were observed to detect the presence of any viable microorganism in porridge samples after two week of storage and it would provide a general indication of the microbiological quality of the food. (Table 4) shows the results for the microbial analysis.

Table 4: Microbial analysis results for porridge samples

Treatment	Time	Total plate count (CFU)	Yeast mold count (CFU)
T1	Initial	00	00
	1st week	00	00
	2nd week	5.5×10^2	3.5×10^2
T2	Initial	00	00
	1st week	8.6×10^1	5.3×10^1
	2nd week	6.0×10^2	5.5×10^2
T3	Initial	00	00
	1st week	00	2.2×10^1
	2nd week	4.9×10^2	3.5×10^2

According to the results of microbial tests, no colonies were observed at the initial stage in any treatment. If there were no colonies on plate from the test sample in the case of products, the number of yeast and mold per millilitres should be reported as less than one (SLS 516: part 1: 1991). The results showed that, T1 and T3 porridge samples were absent in total plate count and yeast and mold count until 1st week. However, the colony count of T2 was 86±0.00. Yet, the sample remained within the safety margins, since it did not exceed the safety limits of 10^5 CFU of total plate count and also for yeast and mold count, (SLS 516: part 1: 1991). Hence, it was under the detection limit and the detection limit was between 15-150 CFU. However, there was a significant increase in total plate count and yeast and mold count after the 2nd week of storage time. Hence, the maximum storage period of the product was recommended as 1 week under refrigerated condition.

RECOMMENDATIONS AND CONCLUSION/S

Ready to serve low fat nutritious porridge can be developed with coconut skim milk and rice with Skim milk-to Rice paste 75% to 25%. Shelf life of porridge was one week in refrigerated condition (4±2^{0}C) without preservatives. T1 sample can be prescribed as an improved best nutritional porridge for the children, youngers and adults. Further studies are needed to improve the storage conditions.

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OPTIMUM CUT SIZE AND DEHYDRATED TIME FOR ASH PRODUCTION USING KING COCONUT HUSK

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ABSTRACT

This study attempts to identify the optimum production conditions to produce ash using king coconut husk, providing a solution for the waste generated in the king coconut water processing industry in Sri Lanka. The suitable moisture content of the husk, the optimum cut size, and the dehydration period was determined by producing ash out of king coconut husk waste. Full, half, quarter, and chip cut sizes of husks were dried in a dehydrator at 60°C for different time periods (0h, 2h, 4h, 8h, 12h, 24h, and 48h). Twenty-eight treatment combinations were ashed in the muffle furnace at 600°C for 4h. The highest ash yield of 7.4 % was obtained from chips-sized particles dried over 24h that reached 2-4 % moisture. Therefore, chips are the most efficient particle size for drying king coconut husk, since they can achieve dryness within 24 hours at 60 °C in continuous drying. When the particle size is larger, it must be dried for 48 hours before being used in the production process. King coconut husk ash produced at the aforementioned optimum condition contained 26 ± 3 % of total K and 46.3 ± 6.01 % of total C pH, and EC of king coconut husk ash ranged from 10 – 11 and 10 µS/cm – 40 µS/cm, respectively. The chemical properties of king coconut husk ash are unaffected by particle size and drying time. However, husks with the lowest moisture content will produce more ash. King coconut husk ash is thus suitable for use for a variety of purposes, including as sustainable soil amendments.

Keywords: King Coconut Husk (KCH), King Coconut Husk Ash (KCHA), Potassium source, Sustainability, Waste

INTRODUCTION

The King Coconut (*Cocoas nucifera var. aurantiaca*) is native to Sri Lanka and a symbol of Sri Lankan hospitality and is commonly served in roadside stalls and upscale hotels (Thampan, 1975; Craig, 2006). Nut water is a highly hydrating beverage that contains natural electrolytes and also packed with vitamins and minerals and has a neutral pH (Shubhashree *et al.*, 2015; Marapana *et al.*, 2017).

King coconuts, with their unique sweet taste and limited availability, hold great commercial potential globally. Even though king coconuts were previously shipped exclusively as wrapped whole nuts (Jayasinghe and Hewajulige, 2021), packaging nut water into tetra packs, glass bottles, and cans has become a realistic strategy to increase its competitiveness in the worldwide market (Umamaheswaran, 2015).

The export market's high demand for bottled king coconut water leads to increased production of king coconut husk (KCH) waste creating an ecological threat while consuming time and labour to manage and transport the large quantity of bio-waste. Moreover, empty husks serve as breeding sites for disease-carrying insects, causing health problems (Ranasinghe and Amarasinghe, 2020).

King coconut husks have been used as dead mulch to conserve moisture, control weeds, and prevent erosion (Shirish *et al.*, 2013). They also provide nutrients improving soil fertility and microbial activity (Shirish *et al.,* 2013; Konduru *et al.,* 2019; Iqbal *et al.*, 2020). However, KCH is less effective than other organic mulches in terms of moisture absorption and decomposition (Hochmuth *et al.,* 2009; Esmailpour *et al.*, 2013). Therefore, mulching and burying KCH in agricultural lands are not economically or environmentally sustainable for managing this bio-waste.

Major king coconut water exporters often use coconut husks as a biofuel feedstock in boilers to generate power. However, its limited availability prevents it from being a viable option for boilers in King coconut water processing factories. (Arachchige and Sandupama, 2019).

Agricultural waste can be repurposed as sustainable soil amendments, fertilizers, or energy sources (Rajagopal *et al.*, 2014). King coconut husk contains three times more potassium than other organic manures. It is a valuable nutrient source for crops and is recommended by the Coconut Research Institute in Sri Lanka. Applying 5.36 kg of coconut husk ash annually per mature coconut palm satisfies its K requirement (Herath and Wijebandara, 2017). Additionally, KCH ash can neutralize acidic soils, enhance magnesium and phosphorus availability by raising soil pH (Herath, 2014).

The demand for organic products highlights the need for organic inputs in agriculture. Sri Lanka lacks organic K sources, but coconut husks provide a valuable solution (Herath, 2014). Despite its lack of market value and low fiber content, King coconut husk is a valuable nutrient source for agriculture. Studies explore using diverse materials like crop residues, livestock, and industrial waste to produce ash for multiple applications (Sweeten *et al.*, 1986; Haykiri-Acma, Yaman, and Kucukbayrak, 2010; Muthaiyan, Bala and Varatharajan, 2019). Produced ash has been utilized as crop fertilizers, air pollution absorbents, catalysts, and in the cement and concrete industries (Moayedi *et al.*, 2019).

Wood ash is typically utilized as a liming supplement but enriches the soil with plant nutrients (Erich, 1991). Nevertheless, Priyadharshini and Seran, (2010) have investigated utilizing paddy husk ash as a K source, which contained 1.31 % K_2O and 0.66 % P_2O_5, applied at a rate of 4.5 tons per hectare to improve the productivity of Sri Lankan cowpea cultivation.

In agriculture, ash is directly applied as fertilizer/soil amendment and indirectly by mixing when producing compost (Koivula *et al.*, 2004). Ash incorporation in composting enriches the nutrient content and its water-soluble nutrients promote crop uptake (Kuba *et al.*, 2008; Asquer *et al.*, 2019). Ash-incorporated compost reduces CO2 emissions in water and aerobic conditions due to buffering capacity, promoting microbial activity and heat production (Agnew and Leonard, 2003; Kuba *et al.*, 2008; Kurola *et al.*, 2011). Ash addition accelerates composting, reduces odour, and enhances mineralization and humification (Kuba *et al.*, 2008).

This study aims to determine the ideal conditions for producing ash from king coconut husks, which can be used as an energy source and partially replace the need for plant potassium. The optimal production conditions, including moisture level and cut size, have not been explored in previous works, causing time and labour consumption during processing.

MATERIALS AND METHODS

The study was conducted in the Agronomy Division of the Coconut Research Institute, Lunuwila, Sri Lanka. Fresh KCH was collected from the “Slivermill” Group of the company at Loluwagoda, Mirigama. In this study, there were two factors: the cut size (whole husk, half husk, quarter husk, and chips), and the dehydration time (0, 2, 4, 8, 12, 24, and 48 hours). There were 28 treatment combinations with three replicates.

Preparation of king coconut husk ash

Fresh king coconut husks were cut into four sizes and dehydrated for the mentioned time intervals. Samples were then dried in a drying oven to determine moisture content and used to produce ash. Dehydrated husks were combusted in a muffle furnace at 600°C for 4 hours (Magtoto *et al.*, 2019). The ash yield was calculated on the dry mass basis of each cut size at different moisture levels as follows (Muthaiyan, Bala and Varatharajan, 2019).

$$\text{Ash Yield \%} = \frac{\text{M1}}{\text{M2}} \times 100$$

Where, M1 is the dehydrated biomass before combustion (g), and M2 is the ash weight (g).

Determination of ash yield and other chemical properties

The pH, EC, fixed C, and K contents of ash samples were examined under various production conditions, including cut size and moisture level. The ash samples were ground, sieved, and prepared for analysis. pH and EC were measured in a solution using a pH and EC meter (Edge meter, Hanna, Romania) (Enders *et al*., 2012), while organic carbon was determined using the Loss-On-Ignition method (Nelson and Sommers, 1983). The K content was assessed according to Enders *et al.* (2012) by adding ash to a solution, filtering it, and analyzing it using an atomic absorption spectrophotometer (AA-7000 series, SHIMADZU Atomic absorption). These methods, with some modifications, were employed to accurately measure the properties of the ash samples.

Statistical Analysis

Statistical analyses utilized Minitab. The drying rate was analyzed with Repeated measure ANOVA. Ash yield and properties were analyzed using two-factor factorial analysis. Best cut size selected via One-Way ANOVA. Mean separation was performed using Duncan's Multiple Range Test (DMRT).

RESULTS AND DISCUSSION

Table 1 shows the effect of cut size and the dehydration time on loss of moisture content, and ash yield.

Table 1: The effect of cut size and the dehydration period on the moisture content of KCH and ash yield

	Moisture Content (%)		**Ash yield (%)**	
	Sig.	**Partial Eta Squared**	**Sig.**	**Partial Eta Squared**
Cut size	<0.001	0.975	<0.001	0.707
Time	<0.001	0.905	<0.001	0.849
Cut size * Time	<0.001	0.866	<0.001	0.598

The study found that smaller cut sizes and shorter dehydration times increased moisture loss and ash yield. These conditions led to a larger surface area and faster drying. The combined effect of cut size and dehydration time on moisture content was smaller compared to their individual effects. Drying time had a greater impact on ash yield than particle size.

Table 2: Effect of cut size and dehydration period on chemical properties of KCHA

	K (%)		pH		EC (mS/m)		Total C (%)	
	Sig.	**Partial Eta Squared**	**Sig.**	**Partial Eta Squared**	**Sig.**	**Partial Eta Squared**	**Sig.**	**Partial Eta Squared**
Cut size	0.727	0.023	0.438	0.047	0.386	0.052	0.403	0.101
Time	0.000	0.529	**0.000**	0.41	0.028	0.216	0.175	0.084
Cut size * Time	0.334	0.270	0.352	0.266	0.387	0.259	0.369	0.263

The impact of cut size on chemical properties was not significant (P>0.05) due to unchanged biomass composition. Similarly, particle size did not affect bio-oil production in pyrolysis (Aguilar *et al.,* 2015). Dehydrated time had a significant effect (P<0.05) on certain chemical properties (K content, pH, EC) of KCHA. No interaction effect was observed between cut size and dehydration time. Fresh husks had 86-87% moisture, and different particle sizes of KCH showed significant differences (P < 0.001) in drying rate at 60 °C (Fig. 1).

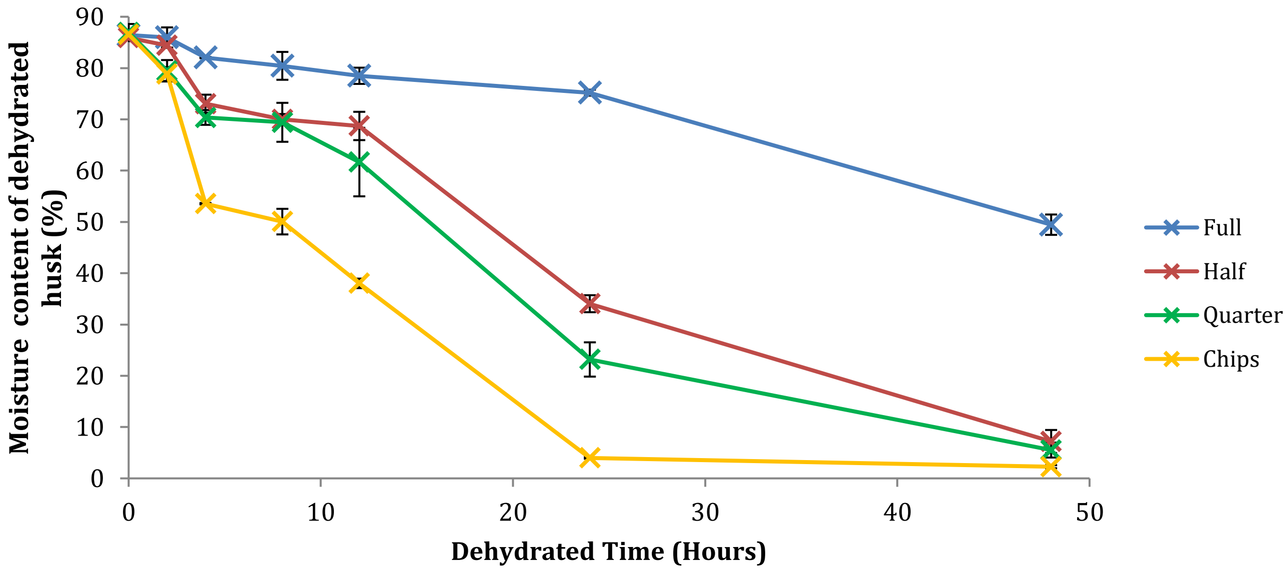


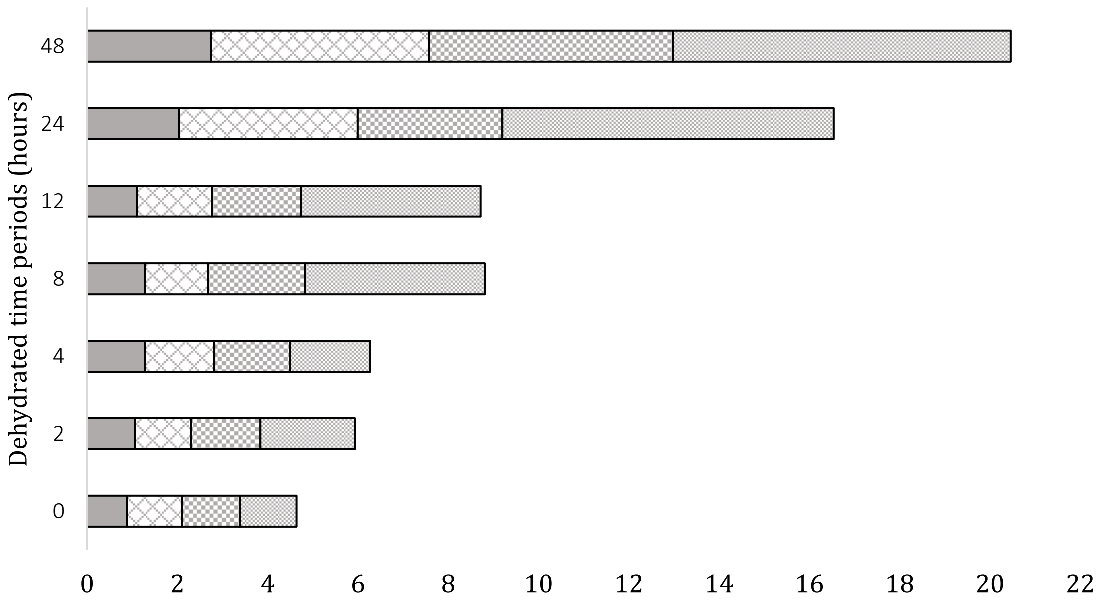
Figure 1: Moisture loss (%) during dehydration at 60°C over time from 0h to 48 h of various husk sizes.

All husk cut sizes, except the whole husk, dried to less than 10% dryness in 48 hours. Within 24 hours, chips removed 10-17% more moisture compared to half and quarter husk sizes. Chips, the smallest cut size, became nearly dry after 24 hours at 60°C. They are the most efficient, reaching dryness in about 24 hours when continuously dried at 60°C. Chips can reduce over 50% moisture in 12 hours and reach below 5% dryness in 24 hours. Larger particle sizes require 48 hours at 60°C to be usable in production.

Ash yield with different moisture content of husk

The highest ash yield is obtained from 48-hour dehydrated chips. The Lowest ash yield was in fresh full husk. Ash yield depends on the cut size.

The ash production increased significantly ($P<0.001$) with increasing dehydration time (Fig. 2). The husk chips with the lowest moisture (2 %) yielded the significantly highest ($P<0.001$) ash yield (7.5 %) when dried for 48 hours at 60 °C, which was not substantially different from the ash obtained from the chips dried for 24 hours. However, ash output was significantly ($P<0.001$) higher in the 24 and 48 hour periods compared to all other drying hours in all cut sizes. This result has clearly shown that lower the moisture contents of the husk, higher the ash output (Fig. 3).



	0	2	4	8	12	24	48
Full	0.88	1.06	1.29	1.29	1.1	2.04	2.74
Half	1.23	1.25	1.53	1.39	1.67	3.96	4.84
1/4th	1.28	1.53	1.67	2.15	1.97	3.2	5.4
Chips	1.25	2.09	1.78	3.98	3.98	7.34	7.48

Ash yeild (%)

Full Half 1/4th Chips

Figure 2: Ash yield (%) of different cut sizes at different dehydration periods

Table 1 shows that reducing the particle size of coconut husks leads to a significant difference in ash yield. When the entire husk is made into chips and dried for 24 to 48 hours, the ash yield increases. Smaller particle sizes result in more heat transfer, leading to better breakdown of biomass and higher ash yield. The composition of larger particle sizes may be less prone to breakdown due to temperature differences. Initial drying time and dehydration duration did not affect ash production significantly.

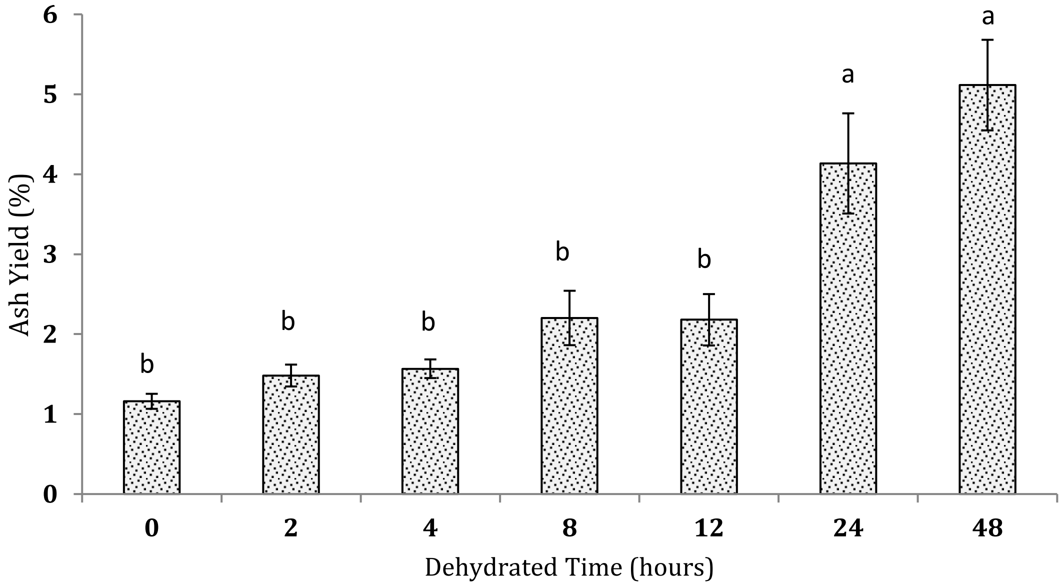


Figure 3: Ash yield (%) at different dehydrated time irrespective of the cut size (N=12, P<0.01)

(Hoque *et al*., 2021) found that rice husk, sawdust, and coconut shell had ash yields of 22.1%, 1.2%, and 0.40% respectively when combusted at temperatures between 650°C and 950°C. However, the ash yield from KCH was 6 times higher than sawdust and 18 times higher than coconut shell. Cuperus and Pels (2011) produced 5.3 kg of ash from 74 kg of fresh cocoa shell, representing around 7% ash content in a combustion plant. Rubber wood contains 4.13% moisture and yields 0.6% ash (Arachchige and Sandupama, 2019), while KCH with 2-4% moisture content produces 7.5% ash under laboratory conditions. Coconut shell gasification at 600°C-900°C resulted in 0.4% ash and 48.92% carbon (Hoque *et al*.,2021).

Effect of drying time on total K content of KCHA

According to the factorial study (Table 2), although particle size has no considerable effect on the potassium content of KCHA (P>0.05), dehydration time has a significant effect (P>0.001) on the potassium content of generated ash. However, dehydrated time showed no noticeable trend as illustrated in the Fig. 4. In this study, the K content of KCHA varied from 18 to 36 % by dry weight depending on the dehydration period.

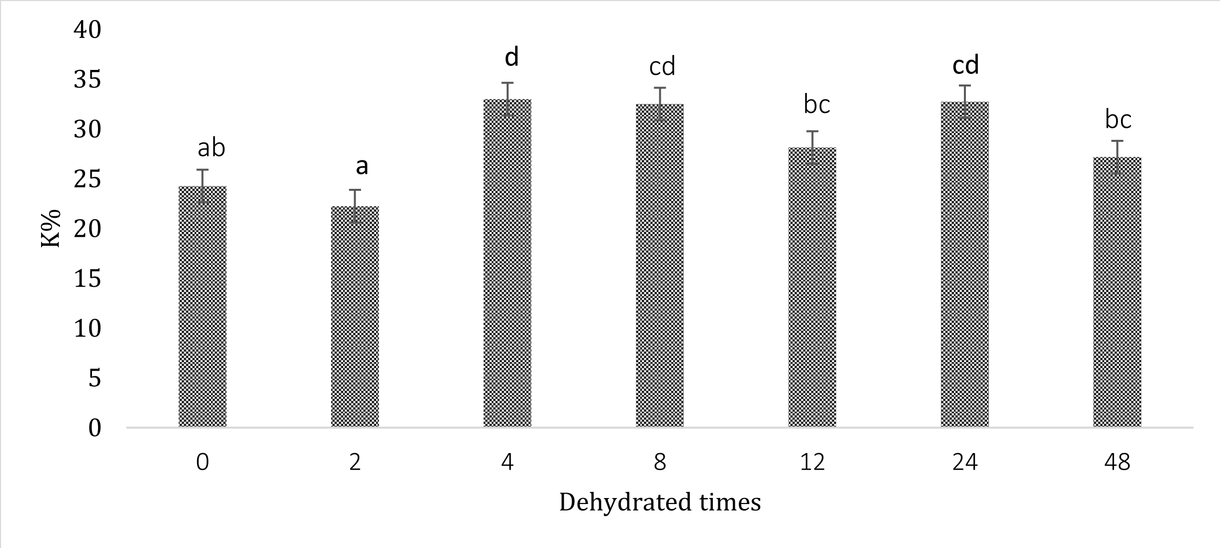


Figure 4: K % of KCHA at different dehydration times irrespective of the cut size (N=12, P<0.001)

A prior study reported the K content of partially burned KCH produced in a kiln at 600°C for one hour ranged 8.8-13.1 %. It has observed a substantial difference between the available K content and ash yield when drying time is increased from 1h to 4h (Herath and Wijebandara, 2017).

The total K content in coconut shell ash was reported in (Muthaiyan *et al.,* 2019) as 7.49 %. K analysis of various biomass ashes; sunflower shell, cotton stalks, cotton gin trash, olive kernel, wheat straw, and switch-grass (*Panicum virgatum*) was conducted using an X-ray fluorescence spectrometer were29.6 %, 25 %, 9-10.8 %, 7.6 %, 5.8-20.8 %, and 1-12.5 % respectively (Vamvuka and Kakaras, 2011). The cocoa shells were burned in a fluidized bed combustion plant to generate energy and recycle the nutrients by forming ash. Produced ash contained 39 % K in cocoa shell ash (Cuperus and Pels, 2011).

When comparing above mentioned popular bio-waste material in other countries, KCH was observed as the highest K-rich material for ash production. The best cut size and the dehydration time, that produced the highest ash yield and K content was determined using a weighted average index. The results of the 28 different treatment combinations (cut size (4) x dehydration time periods (7)) were ranked, and the highest K-contained ash yield was obtained from the chip-sized particles dehydrated for 24 h at 60°C.

Effect of drying on total C in KCHA

There was no significant difference (P>0.1) in total C of KCHA produced in all cut sizes. The total C of KCHA in this study ranged from 16 - 54 % on a dry mass basis (Table 4).

Table 4: Total Carbon content (%) of different cut sizes at different dehydration periods.

Time	Full	Half	Quarter	Chips
0	28.32	53.67	33.57	22.18
2	32.23	34.89	36.01	23.39
4	28.26	34.94	34.76	46.34
8	33.13	27.21	35.52	32.02
12	43.31	26.44	35.44	16.58
24	45.35	30.91	47.96	24.40
48	39.39	40.96	50.89	40.15
CV value	39.88	40.47	37.55	45.18
P value	>0.1	>0.1	>0.1	>0.1

Total C content in the ash produced using rice husk, sawdust, coconut shell, and cocoa shell varied as 39.6 %, 49.58 %, 48.92 %, and 5 % (Cuperus and Pels, 2011; Hoque *et al.,* 2021). Compared to the C concentration of KCHA, coconut shell, and sawdust-like material showed similar values in their ash.

Effect of drying on pH and Electrical conductivity of KCHA

According to the results, pH values of KCHA ranged between 9.92 –11.05 without a significant difference (P value > 0.05). Soil pH 5.5-7.5 is acceptable for most plants as most nutrients become available in this pH range (Islam, Edwards, and Asher, 1980; Fageria and Zimmermann, 1998).

Electrical conductivity ranged from 10 -40μS/cm without a significant effect (P>0.1) of dehydration time. The yield of many crops has been reduced when the soil EC reaches 4dS/m (Richards, 1954). As a soil amendment or a nutrient source for fertilizer, the EC values of KCHA were ideal.

Table 5: Properties of KCHA produced under optimum production condition

Properties	Unit	Values ± SE
Moisture Content of husks	%	3.99 ± 0.13
Ash Yield	%	7.34 ± 0.85
Total K	%	25.88 ± 3.10
Total C	%	46.35 ± 6.01
pH		10.52 ± 0.10
EC	mS/m	13.43 ± 2.75

Compared to all produced biomass ashes from cotton stalks, cotton gin trash, olive kernel, wheat straw, and switch grass, (Cuperus and Pels, 2011; Vamvuka and Kakaras, 2011; Muthaiyan *et al.,* 2019; Hoque *et al.,* 2021) KCHA has the greatest K content. In Sri Lankan scenario, meeting the K requirement for agronomic applications is crucial. According to (Rosenfeld *et al.,* 2004), the high carbon content of wood ash aids in reducing the odour emission of composting. Containing 16 - 54 % of C in KCHA is a good sign for incorporating it in compost production to prevent odour emission. The pH and EC of KCHA were in an acceptable range for producing compost according to (Adhikari *et al*., 2008) and (Kurola *et al*., 2010). Future field investigations are encouraged to use KCHA as a potential soil amendment to supplement the K requirement of plants without affecting crop growth and yield.

RECOMMENDATIONS AND CONCLUSION/S

The study concludes that KCHA is a promising soil amendment for supplementing plant K requirements, especially in high-demand crops like perennial coconuts. Reducing particle size speeds up drying and increases ash production. Chips are the optimum size for ash production, reaching desired dryness faster. Ideal dehydration time is 24 hours at 60°C, with 26% K content and 4% moisture. KCH ash's chemical properties remain unaffected by size and drying time. Ash from KCHA is an eco-friendly and valuable soil amendment for coconut cultivation.

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EFFECT OF SLOW RELEASE FERTILIZER TECHNIQUES ON GROWTH AND MINERAL COMPOSITION OF IMMATURE *HEVEA BRASILIENSIS* AND FERTILITY OF RUBBER GROWING SOILS

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ABSTRACT

To meet the demand of greater nutrient uptake efficiency and mitigate environmental pollution, slow release fertilizers (SRFs) have been developed. The aim of this study was to assess two types of SRFs on plant growth, soil and plant nutrient levels of immature rubber. Two different SRFs; Encapsulated Coir Brick (ECB) and Reusable Fertilizer Porous Tube (RFPT) were evaluated using their two types; type1 and type 2 respectively. A single application of SRFs were compared with split applications of conventional inorganic fertilizers recommended for immature rubber plants as a control treatment where plant-grown Boralu and Homagama series of soil. Growth of rubber plants was monitored by measuring plant girth throughout the experimental period at twenty-four months, thirty months and thirty-six months intervals. Macronutrients in foliar and soil samples were determined at the same time to assess the nutritional status and further measured some important soil fertility parameters. Girth of the immature plants, their foliar nutrients and some soil fertility parameters were measured that received ECB type 1,2 and conventional recommended fertilizer applied control treatment at Raigama estate showed no significant differences (p=0.05) after twenty-four months and thirty months from the beginning of the experiment. Girth of the immature plants at Ganepalla estste and Elston estste that received ECB type 2 and RFPT type 2 respectively, were significantly higher (p=0.05) (17% and 19% respectively) at the end of experimental period (thirty-six months and thirty months respectively) compared to that in control treatment. Application of two types of ECB and control treatment gave almost identical foliar macronutrients; nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg) and soil total N, available P, exchangeable K, calcium (Ca), Mg and pH. However, two types of RFPT treatment showed better or comparable performance with foliar nutrient contents, soil fertility parameters; organic carbon, and total nitrogen contents compared to the control treatment. Moreover, significantly lower levels (p=0.05) of available P content could be observed in RFPT treatments compared to the control treatment (T1) and those P levels were within the suitable range of rubber (12-30 ppm) and could not be observed a significant difference (p=0.05) in plant growth.

Considering the measured assessments of plant girth, leaf nutrients and some soil fertility parameters, there is a possibility of using single application of ECB and RFPT as a substitute for conventional split application of recommended fertilizers for immature rubber plants.

Keywords: Immature rubber, Plant growth, Plant nutrients, Slow-release fertilizer, Soil nutrients

INTRODUCTION

The continuous exploitation of soils for a monocultural cropping systems reduces fertility and productivity of soils primarily due to degradation of physical, chemical and biological properties encouraged by soil erosion, reduction of soil organic matter, alteration of pH and nutrient removal by crops as well as by leaching. However, the soil degradation under rubber is comparatively low compared to other land use. However, the sequential reduction of fertility of rubber growing soils seems considerable.

In general, the soils of the rubber growing districts in Sri Lanka are gravelly, highly porous and deficient in plant nutrients and consequently, considered as less suitable for arable farming according to the standard land classification (Dasanayake *et al.,* 1999). In order to maintain the overall soil fertility, it is essential to apply fertilizers and manure with matching land management.

In relation to plant nutrients, the Rubber Research Institute of Sri Lanka (RRISL) recommends fertilizer mixtures containing the major nutrients required by the rubber tree *viz* N, P, K and Mg based on long-term field experiments (Silva,1971; Pushparajah,1977; Yogaratnam *et al.,* 1984a; Samarappuli *et al*., 1993; Dissanayake *et al*., 1992 &1994; Dharmakeerthi *et al*.,1997).

As at present, mineral fertilizers are considered as the major source for maintaining the soil chemical fertility. Their widespread use has also focused on the possibilities of environmental pollution. With only about half of the applied fertilizers getting into the crop (Bockman *et al.,* 1990), there is a potential for marked economic loss of nitrogen, phosphorus, potassium and magnesium that could occur through leaching and runoff while nitrogen could get lost also through volatilization and denitrification. Meanwhile fertilizer prices have skyrocketed and that may badly affect fertility management procedures in agricultural crops. Besides, cost of fertilizers, low fertilizer use efficiency and continuous use of large doses of inorganic fertilizers and their consequent negative repercussions have drawn attention to think of alternative novel approaches in fertilizer use. The use of slow release fertilizers has been shown to reduce risk of nutrient losses from the crop root zones, as nutrient release rate is synchronized with crop nutrient demand (Hauck, 1985; Goertz, 1991; De Silva *et al.,* 1996). In general, slow-release fertilizer has mainly focused on coated fertilizers. These fertilizers can be physically prepared by coating granules of conventional fertilizers with various materials that reduce their dissolution rates (Shavit *et al*., 2002). Most often, slow-release fertilizers coated with plastic resin or sulfur-based polymers which may slowly break down from water, heat, sunlight, and/or soil microbes. To develop environmentally friendly fertilizers, an effort has been put to utilize eco-friendly coating materials such as; Chitosan, extracted from crustaceans, sodium alginate extracted from brown seaweed, starch and its derivatives, cellulose and their derivatives, agricultural residues, biochar, and polydopamine are the materials commonly used for making environmentally friendly coated slow-release fertilizer types (Chen *et al*., 2018). Although, SRFs could have more benefits in nutrient use, to date these products have been demonstrated to be exceedingly expensive. Therefore, the application of slow release fertilizers for the crops spread over a large area is an expensive operation and will not be practicable. Considering above mentioned difficulties and constrains associated with different fertilizer application practices, attempts were made to introduce slow release techniques i.e. Encapsulated Coir Brick (ECB) and Reusable Fertilizer Porous Tube (RFPT) for rubber plantations.

Low soil fertility is considered as one of the most important constraint on improved agricultural production effective up to economical levels (Samarappuli *et al.,* 1998; Ayoub, 1999). To meet the increasing demand under such situations, proper nutrient management is essential to sustain high crop performance through soil nutrient enrichment. High cost of fertilizers, low fertilizer use efficiency and continuous use of large doses of inorganic fertilizers and their negative environmental impacts have drawn attention to think of alternative approaches in fertilizer use.

This study was conducted to evaluate the effectiveness of two types of slow release fertilizer on growth of immature rubber plants, foliar nutrients and soil fertility under field conditions.

MATERIALS AND METHODS

Experiments were laid down at Raigama, Ganepalla and Elston estates in 2017, 2018 and 2019 respectively to study the effectiveness of different types of SRFs on soil fertility, and their influence on mineral composition of rubber leaves and growth of *Hevea* immature plants. Young budding polybag plants were planted in the field with the onset of rains. Treatments were arranged in a Randomized Complete Block Design with five replicates and 25 plants per each replicate. Two months after planting, treatments were imposed according to the pattern shown in Table 1. N, P, K and Mg containing fertilizer mixture R/U 12:14:14 and kieserite or dolomite were applied as two different SRFs and 100% of the RRISL recommended inorganic fertilizers for immature rubber was applied as control treatment.

SRFs were applied as once per year and fertilizers for control treatment were applied at three months intervals as four split applications per year for first two years and third year onwards fertilizers were applied at four months intervals as three applications per year throughout the experimental period. During the first year after planting, the all fertilizers were applied in a circle, free of weeds, 25-30 cm from the base of the plant. The radius of the circle increases with age about 20-25 cm per year.

Table 1: Treatment combinations of the different experiments of ECB and RFPT

Treatment	Description
T1	Recommended fertilizers; 275g of NPK mixture R/U 12:14:14 with 75g of kieserite for 1st year plants, 550g of NPK mixture R/U 12:14:14 with 150g of dolomite for 2nd year plants and 800g of NPK mixture R/U 12:14:14 with 200g of dolomite for 3nd year plants and all combinations were applied as splits
T2	T2-ECB 40% of the recommended quantity of NPK mixture and kieserite for ECB type 1 T2-RFPT 50% of the recommended quantity of NPK mixture with filling medium No1 for RFPT type1 and separately applied full amount of Mg containing dolomite
T3	T3-ECB 50% of the recommended quantity of NPK mixture and kieserite for ECB type 2 T3-RFPT 50% of the recommended quantity of NPK mixture with filling medium No 2 for RFPT type 2 and separately applied full amount of Mg containing dolomite

Growth assessments

Stem girth measurements were taken at 120 cm from the ground level (Tillekeratne and Nugawela, 2001) at 24, 30 and 36 months after planting from each plant in each replicate.

Soil analysis

Soil samples were taken from each replicate from three points across the replicate at the depth of 0-15 cm using soil augers. Samples within the replicate were bulked separately and then subsamples of approximately 1 kg of soil were taken and allowed to air dry. The pH (1:2.5 soil: water) and organic C (Walkley and Black, 1947) were determined as the basic soil properties. Nutritional status of the soils was characterized by determining total N by Se/H_2SO_4 digestion, available P by NH_4F/HCl extraction, and exchangeable K and Mg by ammonium acetate extraction. Nitrogen and P contents in the extractions were determined colorimetrically using a SEAL Analytical AS2 auto analyzer whereas K and Mg in the extractions were determined using a GBC SavantaAA atomic absorption spectrophotometer.

Foliar nutrient analysis

Two mature foliar samples were collected from the middle whorl of the plant and composited the samples of the randomly selected four plants to form one representative sample per each replicate. Foliar samples were followed the Kjeldhal digestion procedure and the nutrient contents in the digestion mixture was determined using a SEAL Analytical AS2 auto analyzer (N and P) and GBC Savanta AA atomic absorption spectrophotometer (K and Mg).

Statistical procedure

Simple statistics of the soil analyses were conducted though SAS statistical package (SAS Institute Inc., 1996). ANOVA was conducted for the data from foliar analysis to identify the differences among different soil groups using SAS statistical package (SAS Institute Inc., 1996).

RESULTS AND DISCUSSION

The assessment of plant girth made for the immature *Hevea* plants of ECB application experiment showed no significant differences (p=0.05) between treatments at twenty-four months and thirty months after commencement of the treatments at Raigama estate (Table 2). The application of nutrients as conventional fertilizers at three/four months intervals in treatment No.1 and one application per annum with slow release concept utilized ECB applied in Treatment No.2 and 3 facilitated similar nutrient availabilities. Hence no significant differences could be observed in plant growth (Table 2).

Table 2: Effect of different fertilizer applications on growth of immature rubber plants

Treatments	Mean girth (cm)	
	At the end of twenty four months	At the end of thirty months
(T1) Conventional fertilizer application	15.66[a]	18.30[a]
(T2) Slow release fertilizer, ECB type 1	16.50[a]	19.03[a]
(T3) Slow release fertilizer, ECB type 2	17.35[a]	20.42[a]

Values in the same column followed by the same letter are not significantly different at p=0.05

Nutrient contents of foliar samples measured at the end of thirty months after commencement of the experiment is given in Table 3. No significant differences could be observed in between different fertilizer application treatments for foliar nutrients N, P, K and Mg. Previous studies showed that soil nutrient levels of N, P, K and Mg in *Hevea* ecosystem are reflected by their nutrient levels of foliar samples more accurately (Tan, 1972; Yew and Pushparajah, 1984). Consequently, application of different fertilizers maintains comparable nutrient levels in soils and their effect could be observed as no significant differences in foliar nutrient levels. Further, this study assessed some soil fertility parameters such as; pH, total N, available P, exchangeable K, Mg and Ca and showed no significant differences (p=0.05) among treatments at the end of thirty months after establishment of the treatment (Table 4).

Table 3: Effect of different fertilizer applications on leaf nutrient contents of immature rubber plants

Treatments	Leaf nutrients (%)			
	N	P	K	Mg
(T1) Conventional fertilizer application	3.01[a]	0.157[a]	0.982[a]	0.272[ab]
(T2) Slow release fertilizer type 1	2.93[a]	0.147[a]	0.905[a]	0.262[b]
(T3) Slow release fertilizer type 2	3.02[a]	0.160[a]	0.957[a]	0.287[a]

Values in the same column followed by the same letter are not significantly different at p=0.05

Table 4: Effect of different fertilizer applications on soil pH, total N, available P, exchangeable K, Ca and Mg of the top soil layer

Assessment	(T1) Control	(T2) Slow release fertilizer type 1	(T3) Slow release fertilizer type 2
pH	5.08[a]	5.39[a]	5.08[a]
Total N (%)	0.09[a]	0.085[a]	0.085[a]
Available P (ppm)	16.49[a]	22.39[a]	21.07[a]
Exchangeable K (ppm)	24.4[a]	22.2[a]	24.6[a]
Exchangeable Mg (ppm)	41.5[a]	48.9[a]	40.17[a]
Exchangeable Ca (ppm)	371.3[a]	309.2[a]	288.2[a]

Values in the same column followed by the same letter are not significantly different at p=0.05

Another experiment was laid down at Ganepalla estate, the assessment of plant girth showed significantly higher values (p=0.05) with the treatment of RFPT type 2 compared to the other two treatments; control and RFPT type 1 (Table 5).

Table 5: Effect of different fertilizer application techniques on plant girth at 36 months after planting

Treatments	Girth (cm)
T1 (Control)	22.18b
T2 (RFPT type1)	23.49b
T3 (RFPT type2)	25.96a

Values in the same column followed by the same letter are not significantly different at p=0.05

Above mentioned treatment combinations were also established at Elston estate to study the effectiveness of treatment combinations under the *Homagama* soil series. Compared to other soil series low soil fertility parameters were observed in the *Homagama* soil series including the soil textural class of sandy loam. The assessment of plant girth showed significant differences (p=0.05) between treatments at 30 months after planting.

The RFPT treatments (T2 & T3) gave significantly higher (p=0.05) girth compared to the control treatment (T1) and RPT type 2 gave significantly (p=0.05) the highest girth compared to other treatments (Table 6).

Table 6: Effect of different fertilizer applications on plant girth at 30 months after planting

Treatments	Girth (cm)
T1 (Control)	15.0c
T2 (RPT type1)	17.29b
T3 (RPT type2)	17.88a

Values in the same column followed by the same letter are not significantly different at p=0.05

Leaf nutrients showed significant differences (p=0.05) between treatments. However, RFPT included treatments; T2 and T3 showed better or comparable performances compared to conventional fertilizer applications. It means plants performed better or equal to conventional practice (Table 7).

Table 7: Effect of different fertilizer application techniques on leaf nutrients at 30 months after planting

Treatments	N%	P%	K%	Mg%
T1 (Control)	2.6c	0.16b	0.805b	0.19a
T2 (RFPTtype1)	2.9a	0.18a	0.77b	0.19a
T3 (RFPTtype2)	2.8b	0.16b	0.88a	0.21a

Values in the same column followed by the same letter are not significantly different at p=0.05

Soil fertility parameters; organic carbon, and total nitrogen contents in RFPT type 1 and 2 showed better or comparable parameters to conventional fertilizer application (T1). It means plants performed better or equal to conventional practice. Soil fertility parameters; K and Mg in RFPT type 1 (T2) showed significantly lower (p=0.05) value compared to the conventional practice (T1). Further, RFPT type2 (T3) showed comparable parameters to conventional practice (T1). The significantly low level (p=0.05) of available P content could be observed in RFPT type 1 and 2 (T2 and T3) compared to conventional fertilizer application (T1). This is obvious as Eppawala Rock Phosphate (ERP) is sparingly soluble phosphorus source and it performs further poor solubilization under this type of slow release concepts. However, low values of available P in the soil with slow release concept within the suitable range of rubber and could not be observed any significant difference (p=0.05) in the growth of rubber plants. The pH values vary significantly (p=0.05) between treatments but within the range of optimum for rubber plants (Table 8).

Table 8: Effect of different fertilizer application techniques on soil fertility parameters at 30 months after planting

Treatments	pH	Organic carbon %	Total N%	Available P(ppm)	Exchangeable K(ppm)	Exchangeable Mg(ppm)
T1 (Control)	5.75b	1.005b	0.11a	41a	86a	37a
T2 (RFPTtype1)	5.86ab	0.99b	0.0925a	22.8b	68b	23b
T3 (RFPTtype2)	5.9a	1.11a	0.11a	24.16b	78a	32a

Values in the same column followed by the same letter are not significantly different at p=0.05

Application of SRFs has been reported to have less N leaching than plants fertilized with water-soluble fertilizers (Chen and Wei, 2018). Trenkel, (2010) suggested that controlled SRFs had an ability to reduce fertilizer usage by 20–30% of the recommended dosage while obtaining the same crop yield. In several field trials in Florida, the citrus trees fertilized with SRFs at 50% of the recommended rate of conventional fertilizers performed equally to 100% of the recommended rate of conventional fertilizers. Further same magnitude of reduction could be observed with Potato with no harm to the yield and reduce the labour cost significantly (Hutchinson *et al.,* 2002). The Plant growth and yield resulting from SRFs application are equal to or better than those produced by conventional fertilizer applied on ornamental plants (Yeager *et al.*, 1993 and Broschat, 1995) field crops (Pack *et al.,* 2006 and Wilson *et al*., 2010) and turf grass (LeMonte, *et al*., 2016). There were no significant differences observed in growth parameters with different SRFs (Soti *et al*., 2015). In the three major grain crops, rice (Yang *et al.,* 2012b; 2013), wheat (Yang *et al.,* 2011), and corn (Ning *et al*., 2012) showed the increase of N use efficiency compared to conventional urea applications. Further, improved N use efficiencies could be observed with polymer-coated urea providing 3.23-26% yield increases compared to conventional fertilizer applications (Wang *et al.,* 2016). Moreover, Yang *et al*., (2012b) observed no significant increase in rice yield with coated fertilizer in the first year. However, yield greatly increased by 18% with coated fertilizer in the second year. Further, some physiological characteristics; chlorophyll content, photosynthetic rate, transpiration rate and chlorophyll fluorescence parameters have been increased significantly and providing24-35% more grain yield and 57-74% more total yield with coated fertilizer treated maize plants when compared to conventional fertilizer application (Dong *et al.,* 2016).

RECOMMENDATIONS AND CONCLUSION/S

In this study it was revealed that the growth of immature rubber plant, their foliar nutrients, major soil nutrients, soil organic carbon and pH were comparable between SRFs; ECB, RFPT treatments and conventional split fertilizer application. Frequently observed better parameters with SRFs compared to conventional practice and rarely observed significantly lower value with SRFs compared to conventional practice. However, those ranges were in suitable range for rubber planting and not any adverse effect could be observed.

Therefore, it can be suggested that there is a possibility of using single application of SRFs; ECB/RFPT as a substitute for split application of conventional fertilizers recommended for immature rubber.

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IMPACT OF THRESHING, BLANCHING, AND DRYING ON FUNGAL INFECTION IN PROCESSING OF BLACK PEPPER (*Piper nigrum* L.)

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ABSTRACT

Black pepper (Piper nigrum L.) can be used in human foods for flavouring, and to incorporate aroma. Good Agricultural Practices (GAP) can reduce the toxigenic fungi growth and dissemination in the post-harvest process. Mechanical damage of the plant material during the post-harvest manipulation may increase the possibility of subsequent fungal contamination. Therefore, the study was aimed to find the potential of fungal infections on black pepper due to the facilitation of different threshing methods and processing procedures in black pepper processing chain. Three types of threshing methods, two types of blanching and two types of drying methods were used as treatments. To determine the fungal infection rate of the black pepper, Serial Dilution Method and Agar Plate Method were used. Number of colonies observed in replicate samples at just after solar drying and mechanical drying and at one month after storage. The fungal infection rate was significantly lower in hand-picked samples compared to other treatments, because the damage to the spikes and the pericarp of the pepper fruits were minimal. The fungal infection rate was significantly higher in sun dried and without blanched samples as it caused much time to dry the pods. Therefore, blanching and machine drying was the best practices in black pepper processing chain.

Key words: Black pepper, Fungal contamination, Processing procedures

INTRODUCTION

Growing and processing of spices provides cash income to a large proportion of rural Sri Lankans particularly smallholders. The value of Sri Lankan spice exports was equivalent to 1% of the total national exports. Among the spices, black pepper (*Piper nigrum* L. plays the second major role among the export agricultural crops in Sri Lanka in terms of foreign exchange earnings. It can be considered as the most widely used spice in the world and it can be considered as 'Black Gold' and the 'King of Spices' because black pepper act as a major component of international spice market and consumption throughout the world (Zachariah and Parthasarathy, 2008).

Black pepper used in human foods for flavouring, and to incorporate aroma. It is susceptible to contamination by toxigenic fungi in the field, during drying and storage. The use of appropriate Good Agricultural Practices (GAP) can reduce the toxigenic fungi growth and dissemination in the post-harvest process.

Harvesting is done manually in Sri Lanka. Different methods of harvesting and threshing are employed in various pepper producing areas including manual plucking by hands and laying a net above the ground, while berries fall and collected once in every 2–3 days. (Mkojera, 2017) Manual plucking by hands is commonly practiced, where spikes with matured berries are handpicked from plants. It helps farmers to select only matured, less damaged fruits, and minimizes bruising of fruits that could allow microbial invasion during drying and storage (Mkojera, 2017). Pepper plucking equipment has been designed and developed to facilitate pepper harvesting (Kahandage, 2017). Pepper plucking equipment and manual plucking by hand were considered harmless harvesting methods, since no damage to spikes and vines were recorded during evaluation (Kahandage, 2017). According to Garduño García *et al*., 2017, the green pepper was the most contaminated due to the degree of ripening and less commercial, hence stored for a longer period, thus increasing the risk of mycotoxigenic fungal growth (Zakaria *et al*., 2022). During the harvesting operation, the moisture content should be determined as it affects drying. High moisture content due to precipitation or morning dew or during late afternoon as it takes a longer time to dry and increase the likelihood of fungus growth and mycotoxin formation (Wijekoon, *et al.,* 2017). Mechanical damage of the plant material during the post-harvest manipulation may increase the possibility of subsequent fungal contamination. The common method for loosen the pepper berries from the spikes are called threshing. This practice of separating pepper berries is done mechanically and manually in Sri Lanka. Manual method is hand beating or by foot. The traditional method of threshing by hand or by foot is very slow, therefore the growers use mechanical threshers to separate pepper berries. Threshing by machines may cause damage to the berries and the berries may exposed to mould growth. The pepper berries are blanched by placing in boiling water for about 10 minutes which causes them to turn dark brown or black in about an hour. During sun drying, berries are raked to ensure uniform colour and to avoid mould development. Drying the berries for 3-5 days reduces the moisture content to about 10%. The dried berries are garbled, graded, and packed in double lined gunny bags. The best moisture content of black pepper to prevent the growth of moulds during storage is found to be 12–14% dry basis (Anon, 2016). The main purpose of the drying operation is to efficiently decrease the high-water content of the just harvested spices to a safe level to get a stable, safe, and good quality product. Drying of crops should begin immediately after harvest and growers should not hold the crop in piles or in bags for long period of time may cause mould growth. Fresh material for spices or source plants should be processed as quickly as possible. Storage with high moisture may increase the mould growth. However, the exportation of dried black pepper has been negatively affected by the pericarp damage of the fruit due to the different threshing methods and fungal formation. Therefore, this study was aimed to find the potential of fungal infections on black pepper due to the facilitation of different threshing methods and processing procedures in black pepper processing chain.

MATERIALS AND METHODS

The research was conducted at Department of Export Agriculture, Matale, by using of three factor factorial design. Black pepper (*Piper nigrum* L.) samples were collected at soon after threshing, blanching, drying and after one month of storage. Three types of threshing methods, two types of blanching and two types of drying methods were used as treatments (Table 1).

Table 1: Treatment combinations

Treatment 01: Threshing by hand.	Treatment 1.1 Blanching	Treatment 1: Sun drying Treatment 2: Mechanical drying
	Treatment 1.2 Without blanching	Treatment 3: Sun drying Treatment 4: Mechanical drying
Treatment 02: Trampling the spikes by foot.	Treatment 2.1 Blanching	Treatment 5: Sun drying Treatment 6: Mechanical drying
	Treatment 2.2 Without blanching	Treatment 7: Sun drying Treatment 8: Mechanical drying
Treatment 03: Threshing by machine.	Treatment 3.1 Blanching	Treatment 9: Sun drying Treatment 10: Mechanical drying
	Treatment 3.1 Without blanching	Treatment 11: Sun drying Treatment 12: Mechanical drying

To determine the fungal infection rate of the black pepper, Serial Dilution Method and Agar Plate Method were used (International Pepper Community, 2019).

According to the Serial Dilution Method, 25g of black pepper samples from each treatment were taken into a shaking bottle separately which contained 225ml of distilled water. 48 test tubes (12 test tubes in rows, 4 test tubes in columns) were taken and poured 9ml of distilled water for each test tube. Then 1 ml of properly mixed sample culture was drawn by using a sterile pipette and then add to the first test tube to make the total volume of 10 ml. This was provided an initial dilution of 10^{-1}. The dilution was thoroughly mixed by emptying and filling the pipette several times. The pipette tip was discarded, and a new pipette tip was attached to the pipette. 1 ml of mixture was taken from the 10^{-1} dilution and was emptied into the second tube. The second tube had a total dilution factor of 10^{-2}. The same process was then repeated for the remaining tubes, taking 1 ml from the previous tube, and adding it to the next 9 ml diluents. As four tubes were used, the final dilution for the fungus were10^{-4} (1 in 10000).
After the preparation of Serial Dilution, Potato dextrose agar medium was prepared. Tetracycline antibiotic was added to the agar medium to prevent the bacterial population. 20 ml of potato dextrose agar medium were poured into each petri plate. 1ml of black pepper culture solution from each treatment were poured into each petri plate. Each

treatment was replicated by three times. The above procedure was followed for all the 12 treatments.

All the petri plates were incubated at 28 ± 1°C with 12 hours alternating cycles of light and darkness. Plates were examined after 2, 8 days of incubation. After the incubation process, characteristics of fungal colonies from top and reverse were noted. Finally, percentages of fungal infection were recorded.

$$\text{Colony forming units/ml} = \frac{\text{Total no. of colonies x Dilution factor}}{\text{Volume of culture plate}}$$

The collected data was statistically analysed to find the significance difference between the treatments using STAR (Statistical Tool for Agricultural Research) software (2019) in two -way ANOVA procedure. Data were analysed using the analysis of variance (ANOVA) technique to evaluate the differences among treatments, and the means were separated using Duncan's multiple-range test.

RESULTS AND DISCUSSION

Number of fungal colonies observed in Potato dextrose agar plates in the treatments just after solar drying and mechanical drying were given in Table 2 and 3.

Table 2: Number of colonies observed in replicate samples at just after solar drying and mechanical drying

Threshing method	Number of colonies observed in replicate samples			
	R1	R2	R3	Total
Hand pick, without blanch, Sun drying	3	2	1	6^{c}
Hand pick, without blanch, Machine drying	0	1	1	2^{d}
Hand pick, Blanch, Sun drying	1	1	1	3^{cd}
Hand pick, Blanch, Machine drying	0	0	0	0^{e}
Threshing by foot, without blanch, Sun drying	4	3	2	9^{b}
Threshing by foot, without blanch, Machine drying	3	1	1	5^{c}
Threshing by foot, Blanch, Sun drying	2	1	1	4^{cd}
Threshing by foot, Blanch, Machine drying	0	0	0	0^{e}
Threshing by machine, without blanch, Sun drying	3	3	3	9^{b}
Threshing by machine, without blanch, Machine drying	5	3	5	13^{a}
Threshing by machine, Blanch, Sun drying	4	4	5	13^{a}
Threshing by machine, Blanch, Machine drying	0	1	1	2^{d}

Mean of the same letter in a column are not significant at P < 0.05

Table 3: Colony forming units/ml at just after solar drying and mechanical drying

Threshing method	Colony forming units/ml
Hand pick, without blanch, Sun drying	2×10^4
Hand pick, without blanch, Machine drying	0.66×10^4
Hand pick, Blanch, Sun drying	3×10^4
Hand pick, Blanch, Machine drying	0
Threshing by foot, without blanch, Sun drying	3×10^4
Threshing by foot, without blanch, Machine drying	1.66×10^4
Threshing by foot, Blanch, Sun drying	1.33×10^4
Threshing by foot, Blanch, Machine drying	0
Threshing by machine, without blanch, Sun drying	9×10^4
Threshing by machine, without blanch, Machine drying	4.33×10^4
Threshing by machine, Blanch, Sun drying	4.33×10^4
Threshing by machine, Blanch, Machine drying	0.66×10^4

According to the Table 3 and Fig. 1, the minimum fungal infection rate was significantly lower in hand-picked samples compared to other treatments, because the damage to spikes and the pericarp of the pepper fruits were minimal as recorded by Kahandage, 2017. The colony forming units/ml in hand-pick, blanch, machine drying sample was zero as the damage to the spikes and the pericarp were almost zero. Similarly threshing by foot, blanch, machine drying was zero as the spikes may have minimal damage during the process. It was observed that threshing by machine caused high damage to spikes during processing and therefore threshing by machine, without blanch, sun drying had a higher number (9×10^4 units/ml) of colonies.

Number of colonies observed in the plates were significantly higher in sun drying (2.38×10^4 units/ml) as it caused much time to dry the pods as well as sun drying is a climate-dependent method, and temperature cannot be regulated. The temperature during sun-drying varied from 25-30^{o}C. Number of colonies observed in the plates were significantly lower (1.21×10^4 units/ml) in machine drying as it dries the pods quicker. On the other hand, in the mechanical dryer temperature was set for 60^{o}C, which was uninterrupted, and it directly affect to the fungal formation in negatively. Number of colonies observed in the plates were significantly higher (3.44×10^4 units/ml) in without blanch as it caused much time to dry the pods. Number of colonies observed in the plates were significantly lower (1.55×10^4 units/ml) in with blanch as it dries the pods quicker. Actually, blanching helps to clean and sanitize pepper fruits. By briefly immersing the produce in boiling water or steam, it eliminates dirt, surface microorganisms, and potential contaminants, enhancing food safety. Number of colonies observed in the plates were significantly lower (1.415×10^4 units/ml) in hand pick as it caused less damage to pods and the pericarp. Number of colonies observed in the plates were significantly higher (4.58×10^4 units/ml) in threshing by machine samples as it caused higher damage to pods and pericarp of the pericarp. According to the zero or minimum colony forming units/ml resulted in hand-picked, blanched, machine dried treatment and similarly zero or minimum colony forming units/ml resulted in threshed by foot, blanched, machine dried treatment. These results indicate the effect of blanching and machine drying. Blanching limited the moisture content of dried pepper 5.33-11.52%, where the moisture content of untreated sun-dried black pepper was more than 12%. Mechanical dryer needed the lowest time over open sun-drying and decreased the moisture % to a safer level (<10%). (Paul S *et al*., 2021) Maximum colony forming units/ml were resulted in machine threshed, without blanched, sun-dried treatment. According to the Dhas and Korikanthimath (2003), the moisture content of sundried pepper was not safe for storage, as moisture content over 12% can increase the chance of insect pest attack and especially fungal attack. Following Fig. 1 shows the colony forming units/ml at just after solar drying and mechanical drying and Table 4 indicate the respective treatment abbreviations.

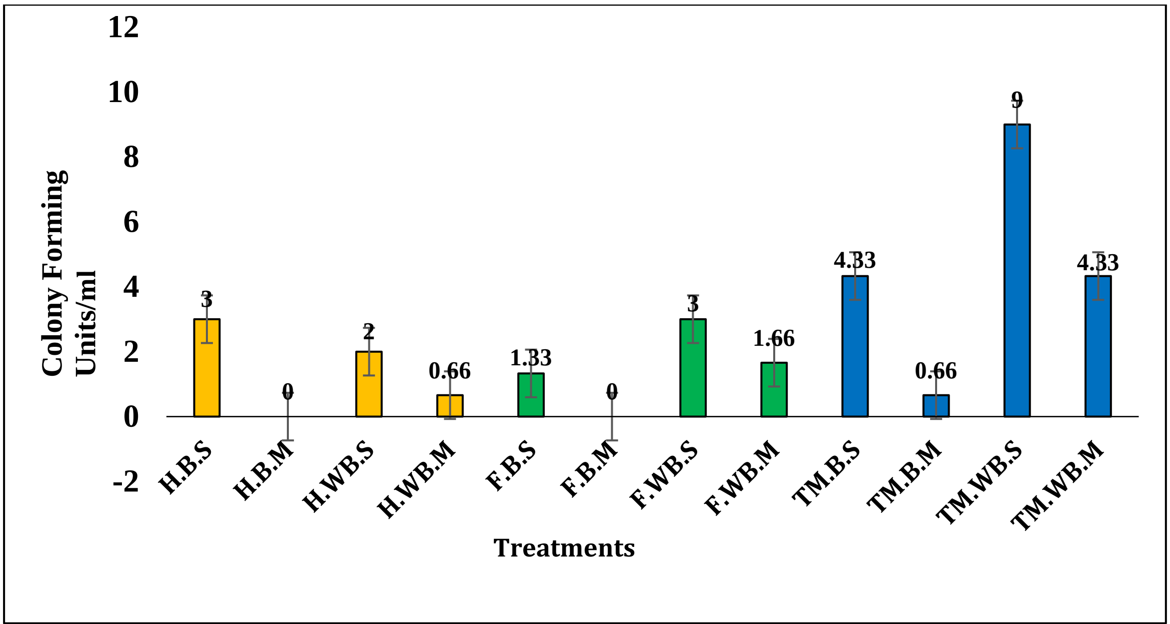

Figure 1: Colony forming units/ml at just after solar drying and mechanical drying

Table 4: Treatment names and Abbreviations

Hand pick, Blanch, Sun drying	H.B.S
Hand pick, Blanch, Machine drying	H.B.M
Hand pick, Without Blanch, Sun drying	H.WB.S
Hand pick, Without Blanch, Machine drying	H.WB.M
Threshing by foot, Blanch, Sun drying	F.B.S
Threshing by foot, Blanch, Machine drying	F.B.M
Threshing by foot, Without Blanch, Sun drying	F.WB.S
Threshing by foot, Without Blanch, Machine drying	F.WB.M
Threshing by threshing machine, Blanch, Sun drying	TM.B.S
Threshing by threshing machine, Blanch, Machine drying	TM.B.M
Threshing by threshing machine, Without Blanch, Sun drying	TM.WB.S
Threshing by threshing machine, Without Blanch, Machine drying	TM.WB.M

Number of colonies observed in Potato dextrose agar plates in the treatments, one month after storage of solar drying and mechanical drying were given in Table 5 and 6.

Table 5: Number of colonies observed in replicate samples at one month after storage

Threshing method	Number of colonies observed in replicate samples			
	R 01	R 02	R 03	Total
Hand pick, without blanch, Sun drying	3	3	4	10[a]
Hand pick, without blanch, Machine drying	1	1	1	3[c]
Hand pick, Blanch, Sun drying	4	2	4	10[a]
Hand pick, Blanch, Machine drying	0	0	0	0[d]
Threshing by foot, without blanch, Sun drying	3	2	5	10[a]
Threshing by foot, without blanch, Machine drying	2	2	3	7[b]
Threshing by foot, Blanch, Sun drying	3	3	1	7[b]
Threshing by foot, Blanch, Machine drying	1	1	1	3[c]
Threshing by threshing machine, without blanch, Sun drying	4	4	4	12[a]
Threshing by threshing machine, without blanch, Machine drying	2	2	3	7[b]
Threshing by threshing machine, Blanch, Sun drying	3	2	2	7[b]
Threshing by threshing machine, Blanch, Machine drying	1	1	1	3[c]

Mean of the same letter in a column are not significant at $P < 0.05$

Table 6: Colony forming units/ml at one month after storage

Threshing method	Colony forming units/ml
Hand pick, without blanch, Sun drying	3.33×10^4
Hand pick, without blanch, Machine drying	1×10^4
Hand pick, Blanch, Sun drying	3.33×10^4
Hand pick, Blanch, Machine drying	0
Threshing by foot, without blanch, Sun drying	2.33×10^4
Threshing by foot, without blanch, Machine drying	1.33×10^4
Threshing by foot, Blanch, Sun drying	2.33×10^4
Threshing by foot, Blanch, Machine drying	1×10^4
Threshing by machine, without blanch, Sun drying	12×10^4
Threshing by machine, without blanch, Machine drying	5×10^4
Threshing by machine, Blanch, Sun drying	7×10^4
Threshing by machine, Blanch, Machine drying	1×10^4

Fig. 2 shows the colony forming units/ml at one month after storage. Storage was done by using of scientific sip lock bags. The minimum fungal infection rate was significantly lower in hand-picked samples compared to other treatments. When considering of the hand-picked sample, zero colony forming units/ml resulted in hand-picked, blanched, machine dried treatment. These results indicate the effect of blanching and machine drying. 3.33×10^4 of colony forming units/ml were resulted for both Hand pick, without blanch, Sun drying treatment and Hand pick, Blanch, Sun drying treatment and 2.33×10^4

of colony forming units/ml were resulted for both Threshing by foot, without blanch, Sun drying and threshing by foot, Blanch, Sun drying treatments. This was resulted due to the sun drying. According to the Dhas, P.A. and Korikanthimath, V.S., 2003, moisture content of sundried pepper was not safe for storage, as moisture content over 12% can increase the chance of insect pest attack as well as fungal attack. Maximum colony forming units/ml resulted in machine threshed, without blanched, sun-dried treatment (12 x 10^4 colony forming units/ml). This was resulted due to the sun drying and the without facilitation of blanching. When considering of the threshing method, minimum colony forming units/ml resulted in hand, picked sample and maximum colony forming units/ml resulted in machine threshed sample. According to the Mkojera, 2017, hand-picked black pepper facilitates less damaged fruits, and minimizes bruising of fruits that could allow microbial invasion during drying and storage. Higher number of colonies observed in the plates which were facilitated in threshing by machine samples as it caused higher damage to pods. When come to the blanching or without blanching, minimum colony forming units/ml resulted in blanched samples than without blanched samples. According to the sun dried and machine dried samples, all the machine dried samples contained lowered colony forming units/ml than sun dried samples. Number of colonies observed in the plates were significantly higher in sun dried-without blanching as it caused much time to dry the pods as well as sun drying is a climate-dependent method, and temperature cannot be regulated. The temperature during sun-drying varied from 25-30 °C. Following Fig. 2 shows the colony forming units/ml at one month after storage and Table 7 indicate the respective treatment abbreviations.

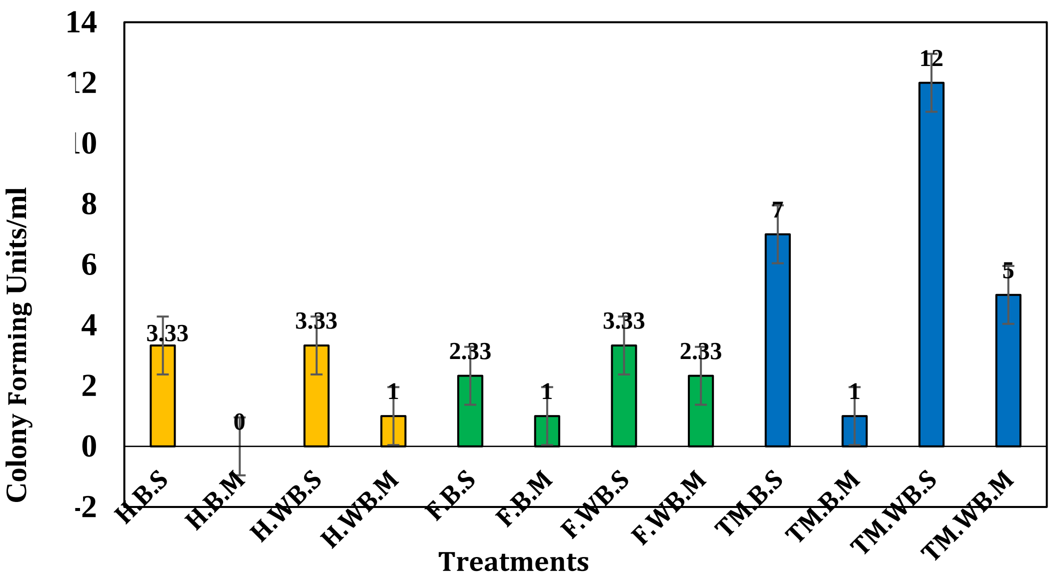

Figure 2: Colony forming units/ml at one month after storage

Table 7: Treatment names and Abbreviations

Hand pick, Blanch, Sun drying	**H.B.S**
Hand pick, Blanch, Machine drying	H.B.M
Hand pick, Without Blanch, Sun drying	H.WB.S
Hand pick, Without Blanch, Machine drying	H.WB.M
Threshing by foot, Blanch, Sun drying	F.B.S
Threshing by foot, Blanch, Machine drying	F.B.M
Threshing by foot, Without Blanch, Sun drying	F.WB.S
Threshing by foot, Without Blanch, Machine drying	F.WB.M
Threshing by threshing machine, Blanch, Sun drying	TM.B.S
Threshing by threshing machine, Blanch, Machine drying	TM.B.M
Threshing by threshing machine, Without Blanch, Sun drying	TM.WB.S
Threshing by threshing machine, Without Blanch, Machine drying	TM.WB.M

When considering of the statistical analysis for just after drying, the coefficients of the hand-picking, foot threshing, machine drying was negatively significant with colony forming just after drying. According to the regression analysis, threshing by threshing machine, sun drying, blanching/without blanching and are highly correlated with other variables. Therefore, all those variables have been removed from the equation. The regression model incorporated with three independent variables which had significant correlations with the potential fungal infection. There were 9 independent variables entered in the model, out of them only 3 variables (foot threshing, hand threshing, and machine drying) had a significant influence at the 5% level. According to the results, the adjusted r^2 is about 62.6%, which does not indicate a serious level of multi collinearity among the variables. Also, the overall significance of the model indicates a level of 0.043 ($p<0.05$) the variable that had the greatest influence on colony forming was "hand-picking" with the co efficient of 3.28 ($p<0.05$), implying the goodness of fit of the model in terms of the study variables. This means one standard deviation increase in the hand-picking decrease the colony forming by 3.28 standard deviation.

When considering of the statistical analysis for one month after storage, the hand-picking, foot threshing and machine drying is decreased the colony formation after one month of storage. According to the regression analysis, threshing by threshing machine, sun drying, blanching/without blanching and damage percentage are highly correlated with other variables. Therefore, all those variables have been removed from the equation. The value for the adjusted r^2 (64.3%) implies the majority of variation in output (y) was accounted for by variables in the model. There were 9 independent variables entered in the model. The effect of hand-picking, foot threshing and machine drying mainly statistically significant (significant at 5 % level) on the colony formation after the one, month storage. Coefficients of these three variables also negatively effect on the colony formation of the after one month storage.

RECOMMENDATIONS AND CONCLUSION/S

Quality of black pepper highly depends on processing treatments such as threshing, blanching, and drying. According to the main threshing methods, potential fungal infection rate was lowered in hand-picked sample because of the less damage for the fruit's pericarp and the spikes. Higher fungal infection rate was observed in machine threshed sample because of the higher damage for the fruit's pericarp and the spikes. When considering of the effect of blanching, minimum or zero fungal infection rates were resulted in all the blanched samples than without blanched samples. Blanching decreased the moisture content of black pepper than untreated black pepper as well as negatively affect to the fungal formation. Blanching limited the moisture content of dried pepper 5.33-11.52%, where the moisture content of untreated sun-dried black pepper was more than 12%. In contrast, untreated pepper could not meet the consumers' desire. All the machine dried samples contained lowered fungal infection rate than sun dried samples because sun drying take much time to dry the pods as well as sun drying is a climate-dependent method, and temperature cannot be regulated. The temperature during sun-drying varied from 25-30^{o}C. On the other hand, in the mechanical dryer temperature was set for 60^{o}C, which was uninterrupted, and it directly affect to the fungal formation in negatively. Therefore, it is better to follow, blanching and machine drying with black pepper processing chain.

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EVALUATING THE FEASIBILITY OF *Megathyrsus maximus* (Guinea grass) AS FODDER AT DIFFERENT HARVESTING INTERVALS

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ABSTRACT

Megathyrsus maximum is an invasive and problematic weed prevalent in various agricultural lands, including coconut plantations. The conventional methods of weed control, such as manual, chemical, and mechanical approaches, prove ineffective against this weed due to its competitive propagation mechanisms and the substantial labor required for weeding. Although Megathyrsus maximum is recognized as a troublesome weed in Sri Lanka, it was initially introduced to the country in the 1820s for use as fodder. Therefore, the objective of this study was to assess the fodder quality of Megathyrsus maximum under local conditions, aiming to utilize it as a beneficial management technique for controlling this weed. The experiment was conducted for five months in an existing guinea grass field, which naturally provided the growth environment. The study followed a randomized complete block design. Plant samples were collected at various growth stages, specifically at 4, 6, 8, 10, and 12 weeks after the initial cutting. Several growth parameters were measured, including plant height, number of leaves, number of tillers, leaf length, leaf-to-petiole ratio, fresh weight of biomass, dry matter yield, and percentage of flowering. The harvested grasses were analyzed for crude protein, crude fiber, and ash contents to assess the availability of nutrients in the leaves for fodder purposes. The results revealed significant differences (P<0.05) in the measured growth and quality parameters at different growth stages. Considering the growth and nutritive parameters of Megathyrsus maximum, it is recommended that the weed be harvested at the 8-week growth stage for optimal utilization as fodder for ruminant animals.

Keywords: Fodder quality, Growth parameters, Growth stage, Leaf nutrient, Megathyrsus maximus

INTRODUCTION

Guinea grass was named *Panicum maximum* until 2003 and later renamed *Megathyrsus maximus* as it belongs to the Genus Megathyrsus. It is a perennial grass under the family Poaceae. This is an erect plant that grows up to 2-3 m under optimum conditions and has several cultivars namely Gatton, Vencidor, Petrie, Mutale, Riversdale, and Makuveni. These cultivars vary in terms of yield potential, forage quality, leaf size, plant height, colour of the plant, and response to nutrients (Aganga., 2003). The thermal responses of guinea grass species vary with their genotype. Some cultivars prefer shading conditions, while others are highly adaptable to warmer climatic conditions (Jayasekera, 2018).

This species is native to the East African region including Kenya, Uganda, Rwanda, Ethiopia, Somalia, and Sudan. However, this plant is now widely spread in countries like Sri Lanka, Iran, India, Indonesia, Malaysia, and the West Indies. *Megathyrsus maximus,* was introduced to Sri Lanka in the 1820s as forage species by Alexander Moon to the Royal Botanical Garden in Peradeniya (Savidan *et al.,* 1989). In Sri Lanka, guinea is a grass commonly known as "Rata tana" or "Gini tana" and most of the river banks, grassy lands, uncultivated public lands, private lands, and roadsides are invaded by this grass (Sathees and Santhiralingam, 2022). Guinea grass is one of the main forage species in the dry zone of Sri Lanka which is preferred by all stages of livestock.

Guinea grass is one of the leading fodder species in the eastern region (Trincomalee District, Ampara, Batticaloa) (Narmhikaa *et al.,* 2019). Currently, it is considered an invasive weed in many agricultural lands, including coconut plantations. Coconut plantations have been invaded by *Megathyrsus maximus,* disturbing the routine practices of the plantations, and thereby increasing the cost of production. Even though mechanical, manual, and chemical weed control methods can be used to control this weed, most manual and mechanical weed control methods are not effective in eradicating it (González Marcillo *et al.,* 2021). as removing the above-ground biomass is not effective due to its rhizomatous nature (Weemsinghe & Chandrasena, 1994). Regrowth occurs easily during the rainy season with the underground perennating parts. Therefore, the application of systemic herbicides is an important practical measure that should be taken to control this weed (Aganga., 2003). However, due to the restrictions of importing systemic herbicides to the country, management of this weed has become a challenge in the present context.

Even though it is considered a weed under Sri Lankan conditions, in many other countries like Brazil, Japan, the USA, and Australia, it is considered a very valuable forage for its excellent forage quality (Karunanayaka *et al.,* 2021).

Guinea grass annually provides 33 t ha^{-1} of total dry matter yield with 9 % of crude protein in stems and 12.7% in leaves (Njarui *et al.,* 2015). Guinea grass shows higher growth rates and biomass production due to its C_4 photosynthetic pathway. It grows in a wide range of soils including sandy, loamy, and well-drained soil and also performs well in nutritionally poor, mildly acidic, neutral, mildly alkaline, very acidic, and very alkaline soils (Njarui *et al.*, 2015). Guinea grass can tolerate high drought conditions and harsh environments. Having a broad root system for storing large amounts of food makes this plant more tolerant to adverse environmental conditions (Am & Erdinandez, 1969).

Even though there are some improved fodder grass varieties (Pusa Giant Napier, Clone 13, Clone 3, etc.) with high forage quality, they need special care like fertilizing, irrigation, pest management, and other agronomic practices to facilitate growth. Propagating these improved grass varieties is also not easy (Benabderrahim & Elfalleh, 2021). Guinea grass has no such constraints and can be easily grown with limited resources. Other than that, guinea grass has low susceptibility to pest attacks (Aganga., 2003). Considering the above advantages, farmers can utilize this invasive weed plant as a forage to manage it beneficially.

However, farmers do not have proper knowledge of identifying the correct harvesting time of guinea grass to receive optimum nutrition composition and yield to utilize them as forage under local conditions (Vidanarachchi *et al.,* 2019). Therefore, this research was carried out to identify the best harvesting time forage by evaluating the fodder characteristics of guinea grass in different growth stages. As a result, the farmers will be benefited from the knowledge of managing this problematic weed efficiently while utilizing this as feed for their livestock.

MATERIALS AND METHODS

Experimental location

The experiment was carried out on a naturally grown existing guinea grass field at Bandirippuwa estate of Coconut Research Institute of Sri Lanka at Lunuwila located in the intermediate zone of Northwestern province.

Experiment and experimental design

Treatments of the experiment were laid according to Randomized Complete Block Design (RCBD) with three replicates. The area of a single plot was $4m^2$. Guinea grass in all the experimental plots was cut at the height of 15 cm from the ground level before initiating the experiment and allowed to regrow in its natural habitat without supplementing any plant nutrients or conducting any weed management strategies. Then, they were harvested according to the treatment plan.

Five treatments were;

T1 – 4 weeks growth stage
T2 – 6 weeks growth stage
T3 – 8 weeks growth stage
T4 – 10 weeks growth stage
T5 – 12 weeks growth stage

Data collection

Plant height, number of tillers, number of leaves, leaf area, leaf: petiole ratio, percentage of flowering, fresh biomass yield, and dry matter yield were recorded as the growth parameters from each experiment plot at different growth stages. 8 plants were taken to record the growth parameters. Grasses were harvested 15 cm above the ground level using a sickle. After that, the dry biomass yield, ash content, crude protein, and crude fiber contents of the harvested grasses were determined. Nitrogen (N) content was analyzed according to the Kjeldahl method (AOAC, 2000). Crude protein content at different growth stages was calculated using the N contents of each treatment (N*6.25) (Batistoti *et al.,* 2012). Ash content was determined after keeping the samples in a muffle furnace at 600°C for 4 hours (Bamikole *et al.,* 2004). Fibre content was determined using the fiber apparatus (Karunanayaka *et al.,* 2021).

Statistical analysis

MINITAB 17 version was used for statistical analyses. Homoscedasticity and normality of all the measured parameters were checked using the normality test, and outlier test, and the spread of data in different treatments was compared by drawing the box plot. Next, the mean, minimum, standard deviation and coefficient of variation (CV) of measured parameters were calculated under descriptive statistics. The mean values of the data will be statistically compared using the one-way analysis of the variance (ANOVA) at 5% significance and Turke's pairwise comparison test.

RESULTS AND DISCUSSION

The effect of different growth stages on dry matter and fresh matter contents

The dry biomass yield at different growth stages of Guinea grass is shown in Fig. 1. A significant difference ($P<0.05$) was observed in the mean values of the dry biomass harvested at different growth stages. The highest dry matter content was received after 10 weeks of initial cutting, which was 5.25 mt/ha. The lowest dry matter content was 0.38 mt/ha and it was recorded in 4 weeks growth stage. The dry matter content has increased with the maturity of the grass; 10 weeks > 12 weeks > 8 weeks > 6 weeks > 4 weeks.

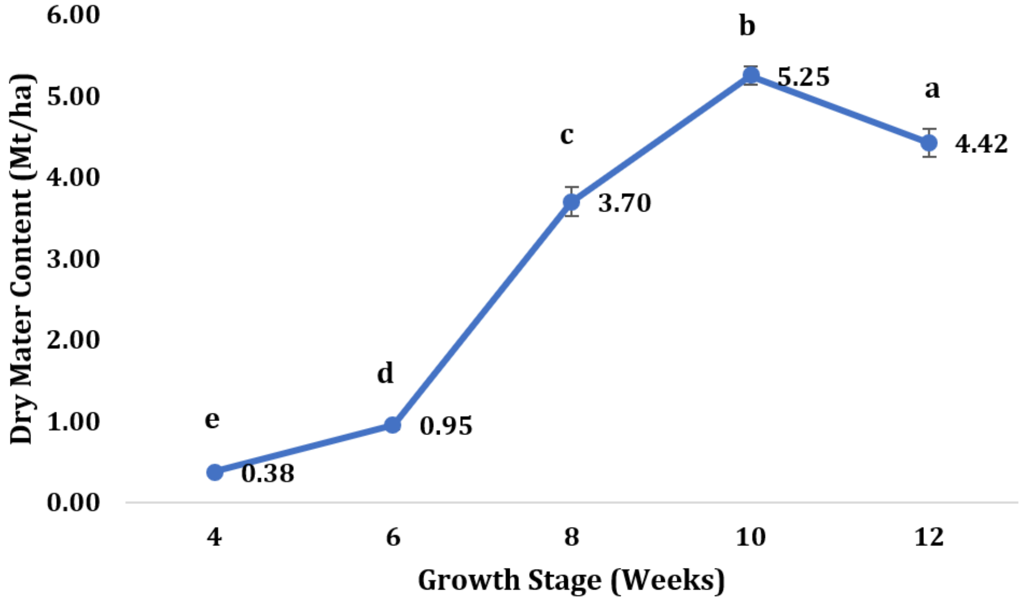

Figure 1: Dry matter content in different growth stages

The current experiment demonstrated that the 10-week cutting interval resulted in the highest dry biomass yield. The growth rate was higher in young grasses, and it reduced after 10 weeks age of Guinea grass. The decrease of the dry matter and fresh biomass yield at 12 weeks of the growth stage may be due to the senescence of the grass after week 10. Similar results have been observed by Lemežienė *et al.,* in 2004 with a reduction in the dry matter content after the vegetative growth.

The fresh biomass yield at different growth stages is shown in Fig. 2. A significant difference (P<0.05) was observed in the mean values of fresh biomass yield at different growth stages. The highest fresh biomass yield was observed at 10 weeks growth stage, which was recorded as 23.08 mt/ha. The lowest fresh biomass yield (1.39 mt/ha) was observed at 4 weeks of growth stage. The fresh biomass yield was also found to be increased with the maturity as 10 weeks > 12 weeks > 8 weeks > 6 weeks > 4 weeks.

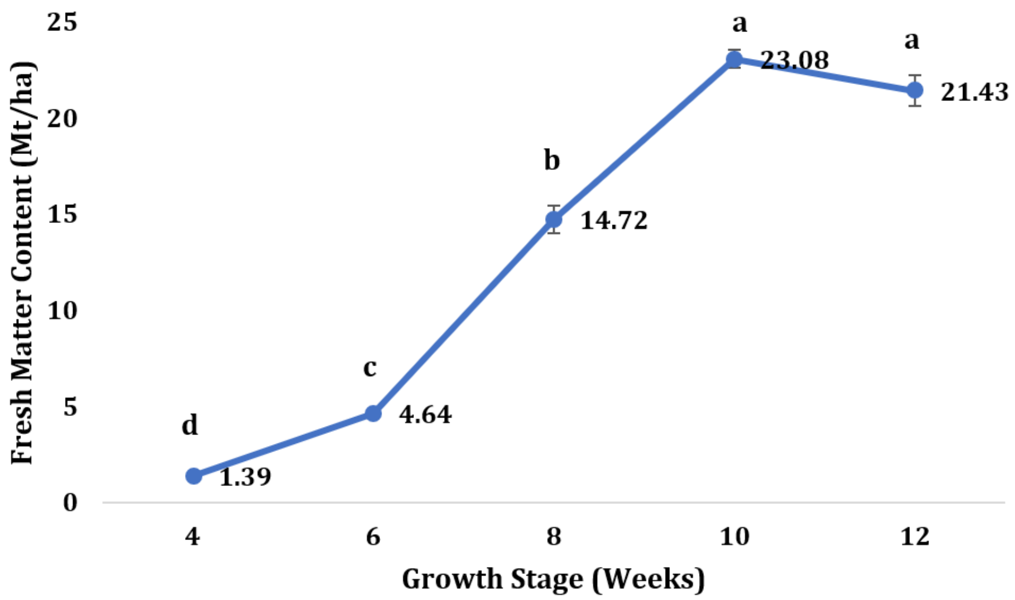

Figure 2: Fresh biomass content in different growth stages

An increase in plant growth attributes like plant height, number of leaves, and number of tillers maximized the plant's fresh biomass content during the early growth stages. These results were supported by the findings of Peiris & Ibrahim, (1995). Similar to the dry matter content, the fresh biomass content was also reduced after the 10th week due to the defoliation of dead leaves.

The effect of different growth stages on leaf area

According to Fig. 3, there was a significant effect ($P<0.05$) in different growth stages on the leaf area. The highest leaf area (8295.34 cm^2) was recorded in 12 weeks growth stage and the lowest leaf area (3034.81 cm^2) was noticed in 4 weeks growth stage. The leaf area was found to increase with the maturity as follows: 12 weeks > 8 weeks > 10 weeks > 6 weeks > 4 weeks.

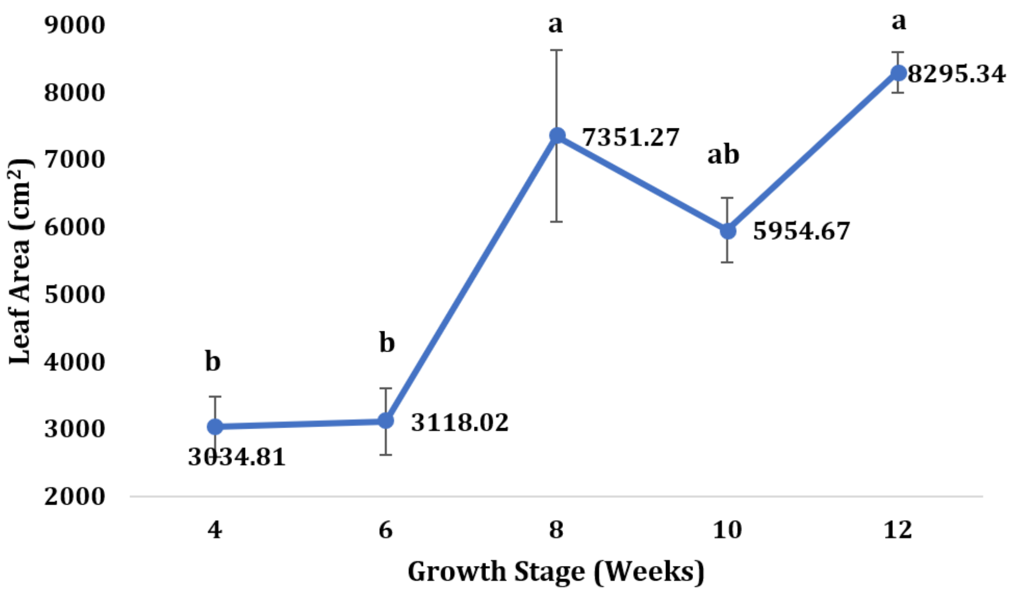

Figure 3: Leaf area in different growth stages

When considering the leaf area, increasing the cutting interval significantly increased the leaf area due to the expansion of dark green foliage, which could intercept and utilize the incident solar radiation mainly in the production of photosynthetic compounds and eventually result in higher meristematic activity and increased leaf area (Leite *et al.,* 2019). But in the present experiment, the leaf area was found to increase with the cutting intervals as follows: 12 weeks> 8 weeks > 10 weeks > 6 weeks > 4 weeks. This difference may be due to the climatic conditions prevailing in the area.

The effect of different growth stages on the leaf-to-petiole ratio

The effect of different growth stages on the leaf-to-petiole ratio shown in Fig. 4. A significant difference ($P<0.05$) was observed in the mean values of the leaf-to-petiole ratio at different growth stages. The highest leaf-to-petiole ratio was observed at 4 weeks after the initial cutting, which was 5.80. The lowest leaf-to-petiole ratio was observed at 10 weeks after the initial cutting, which was recorded as 3.89. The leaf-to-petiole ratio was found to decrease with the grass maturity as follows: 4 weeks > 6 weeks > 8 weeks > 12 weeks > 10 weeks

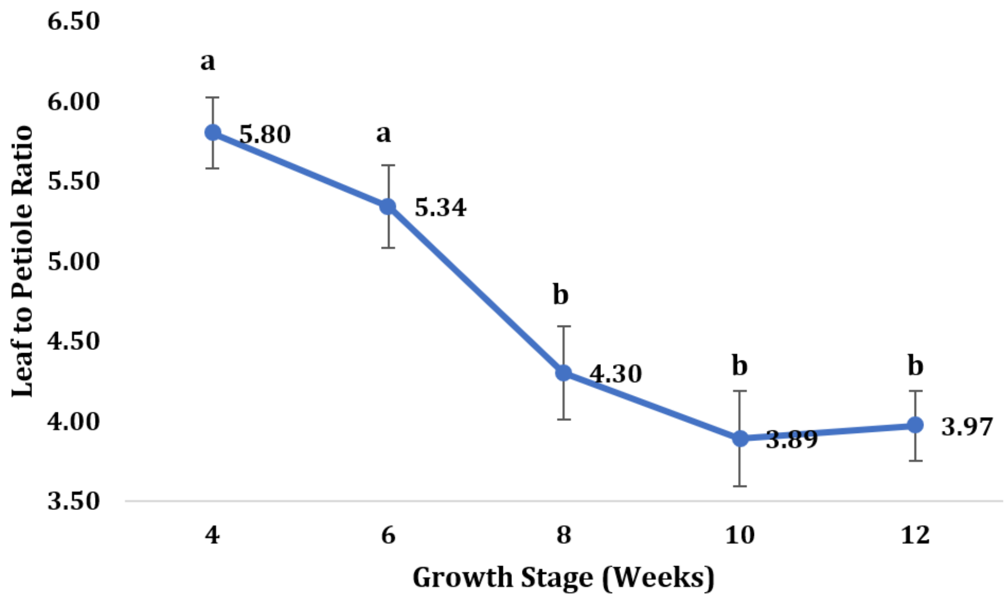

Figure 4: Leaf-to-petiole ratio in different growth stages

The leaf-to-petiole ratio decreases with the grass maturity as the leaf stem elongation happens. A longer petiole contributed to higher light acquisition per unit leaf area as a result of reduced leaf area clustering around the stem (Van Man & Wiktorsson, 2003). Sumamal & Lowilai, (2015) had observed similar observations in their experiment.

The effect of different growth stages on plant height

The effects of different growth stages on plant height is shown in Fig. 5. A significant difference ($P<0.05$) was observed in the mean values of plant height in different treatments. The highest plant height was observed in 8 weeks growth stage, which was 117.75 cm. The lowest plant height was observed in 4 weeks at 57.60 cm. The plant height was found to increase with the maturity of the grass as follows: 8 weeks > 12 weeks > 10 weeks > 6 weeks > 4 weeks.

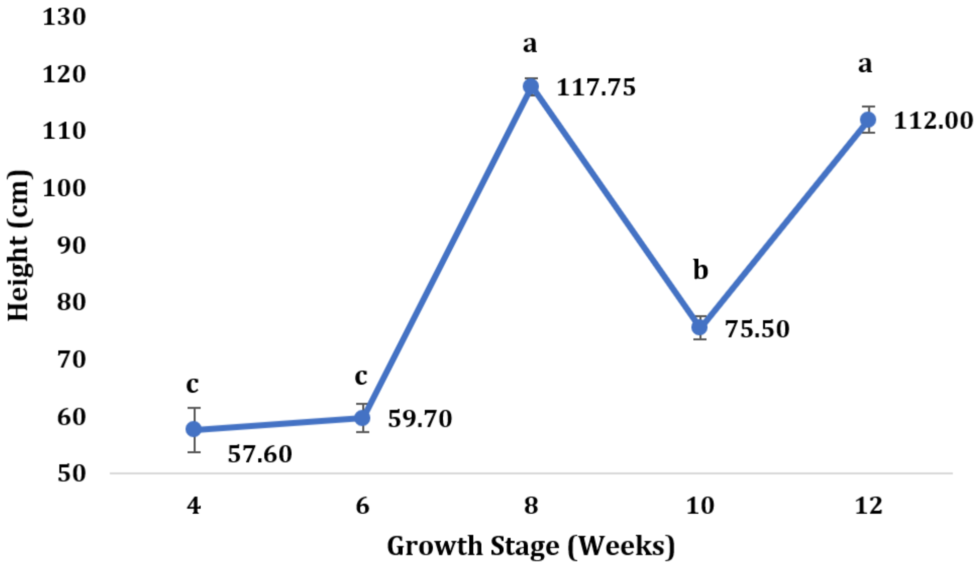

Figure 5: Plant height in different growth stages

Plant height with sufficient nutrient uptake results in higher vegetative growth, increased cell division, and elongation (Peiris & Ibrahim, 1995). The present experiment showed an increase in plant height in the early growth stages. After the 8 weeks growth stage, the plant height has shown a slight change as a result of the dying and defoliation of mature leaves (Van Man & Wiktorsson, 2003). A similar observation was reported by Ram & Trivedi (2013). Plant height has been reduced at the 10th growth stage due to the lodging of the bush.

The effect of different growth stages on the flowering percentage

Fig. 6 illustrates the effects of different growth stages on the percentage of flowering. The effect of different growth stages was significant on the percentage of flowering. The highest percentage of flowering was observed in 12 weeks, which was 70.23%. The lowest flowering was observed at 8 weeks of growth stage and this is the stage that can be considered the pre-anthesis in which guinea grass is most suitable to be harvested as fodder (Muir, 2004).

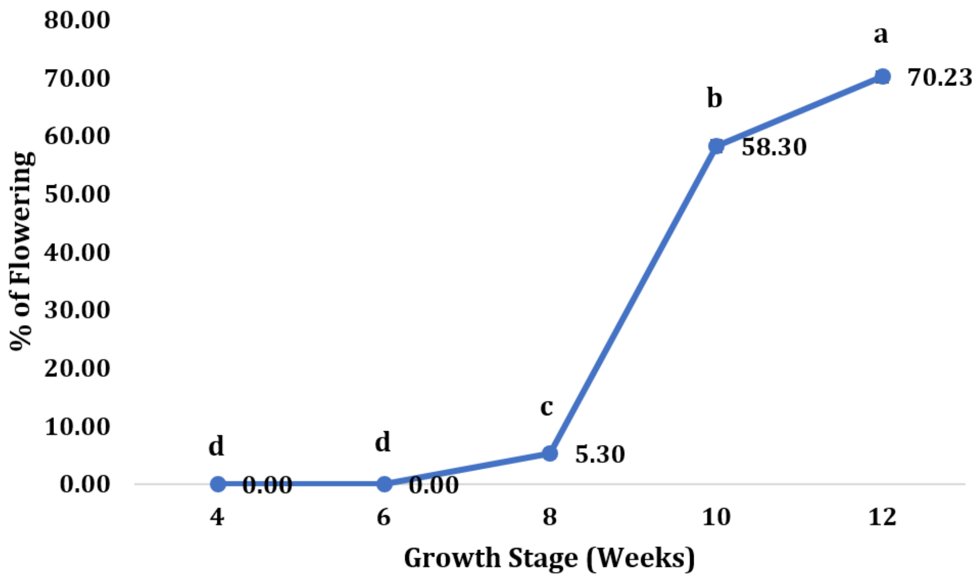

Figure 6: Percentage of flowering in different growth stages

As the vegetative phase of the plant was converted into the reproductive phase during the experimental period, the flowering percentage increased gradually with maturity. Previous research by Muir & Jank (2016) suggested that guinea grass has ideal quality when harvested in the pre-anthesis stage. Accordingly, 8 weeks growth stage can be taken as the ideal harvesting stage for cutting grass.

The effect of different growth stages on the number of tillers

The effect of different growth stages on the number of tillers is shown in Fig. 7. A significant difference ($P<0.05$) was observed in the mean values of the number of tillers harvested at different growth stages. The highest number of tillers was received at 8 weeks growth stage, which was recorded as 13.13. The lowest number of tillers was observed in 4 weeks growth stage, which was 7.29. The number of tillers was found to increase with the maturity of grasses as follows: 8 weeks > 12 weeks > 6 weeks > 10 weeks > 4 weeks.

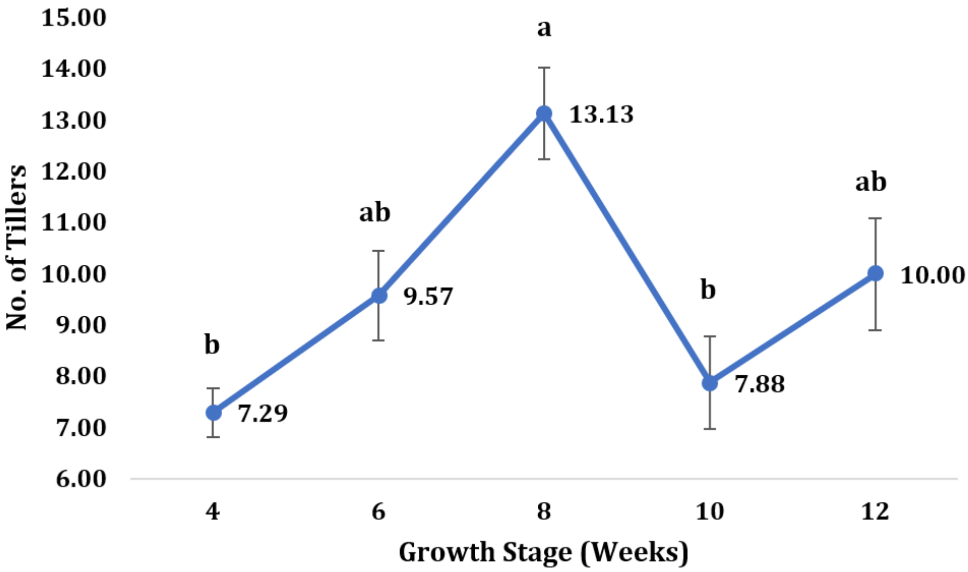

Figure 7: Number of tillers in different growth stages

There has been a noticeable reduction in the number of tillers because some mature tillers have begun to die after 8 weeks of growth as shown by Sumamal & Lowilai, 2015.

The effect of different growth stages on the number of leaves

The effect of different growth stages on the number of leaves is shown in Fig. 8. A significant difference (P<0.05) was observed in the mean values of the number of leaves at different growth stages. The highest number of leaves (100.75) was recorded at 8 weeks growth stage while the lowest (51.6) was observed at 4 weeks growth stage. The number of leaves was found to increase with the maturity of the grass as follows: 8 weeks > 12 weeks > 6 weeks >10 weeks > 4 weeks.

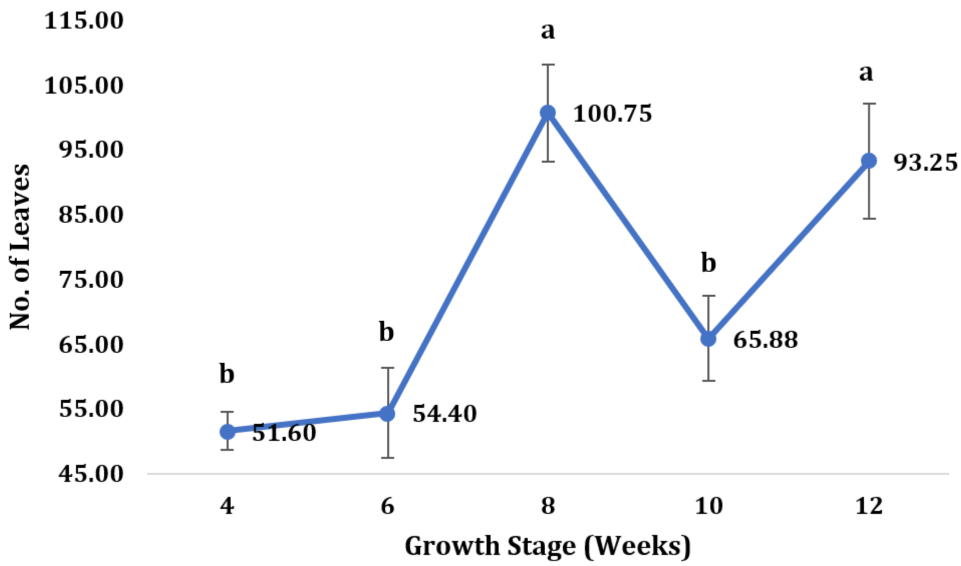

Figure 8: Number of leaves in different growth stages

At the 10-week growth stage, there was observed a decrease in the number of leaves compared to treatment 3. This reduction can be attributed to the response of more mature leaves to defoliation after 8 weeks. Although new leaves continued to emerge after the 10-week growth stage, they did not reach their maximum potential within the duration of this experiment. The outcomes of this study align with the research conducted by Van Man & Wiktorsson (2003).

The effect of different growth stages on crude protein, ash, and crude fiber content (%)

Fig. 9 illustrates the effects of different growth stages on crude protein content (%). Crude Protein is the total quantity of protein in forage, a portion of which is insoluble or non-degradable. There is a significant difference ($P<0.05$) in the crude protein content (%). The highest crude protein content (%) was received at 4 weeks growth stage, which was 9.46%. The lowest crude protein content (5.60%) was observed in 6 weeks growth stage. The crude protein content (%) was found to increase as follows:4 weeks> 8 weeks>12 weeks>10 weeks>6 weeks.

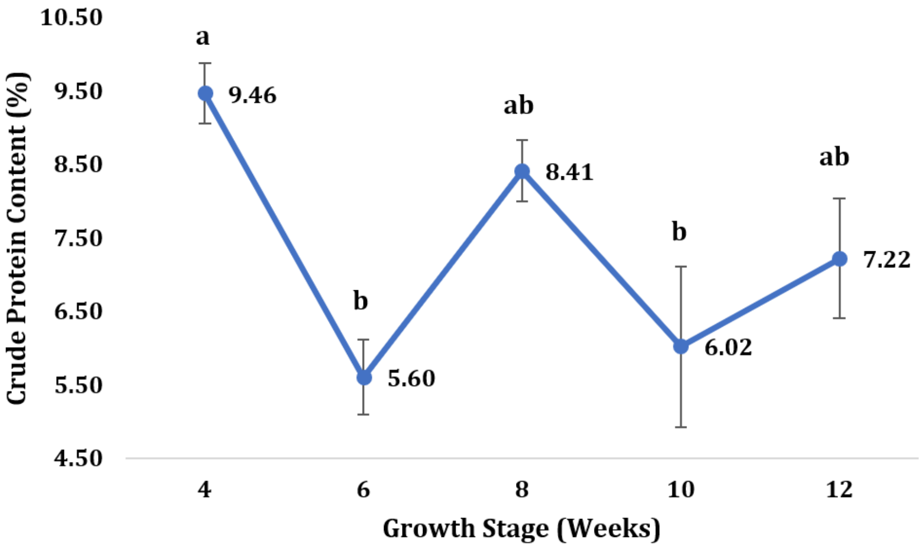

Figure 9: Crude protein content in different growth stages

The higher crude protein yield was obtained due to photosynthetic activity that leads to cell division and elongation, resulting in more production and photosynthesis, which tends to higher crude protein content (Peiris & Ibrahim, 1995). Even though 4 weeks growth stage produces the highest forage quality, since grass dry matter production is not sufficient in that stage, that stage is not recommended for harvesting Guinea grass.

The effect of different growth stages on crude fiber content (%) is shown in Fig. 11. A significant difference (P<0.05) was observed in the mean values of crude fiber content (%) at different growth stages. The highest crude fiber content (%) was recorded at 12 weeks growth stage, which was 39.1%. The lowest crude fiber content (%) was recorded at 4 weeks growth stage, which was 31%. The crude fiber content (%) was found to increase along with the maturity of the grass.

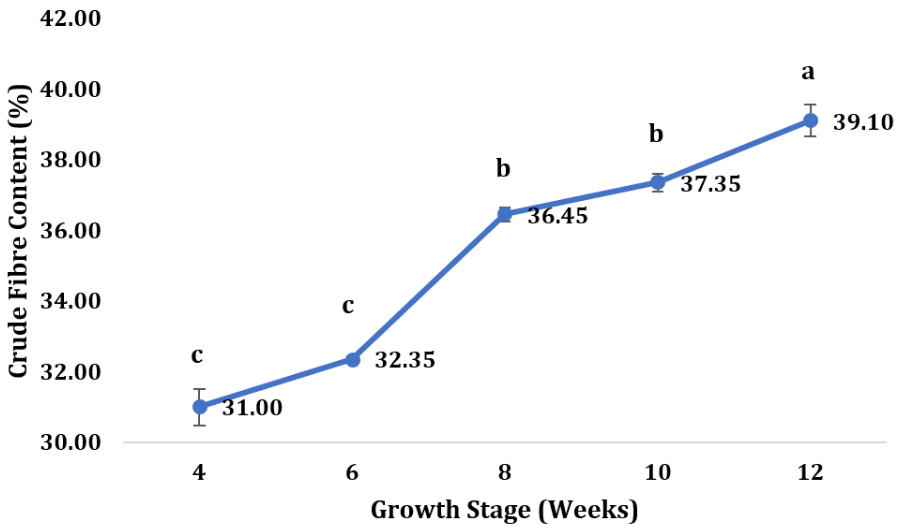

Figure 10: Crude fiber in different growth stages

The concentrations of crude protein and total dietary fiber were more impacted by maturity. Incresing lignin, cellulose, and hemicellulose content with the plant maturity may be the reason for enhancing crude fiber content with the growth stage. A similar observation was reported by Ordoveza *et al.*, (1967). In field observations, 12 weeks of grasses resulted in a hard, fibrous forage with many dead leaves.

The effect of different growth stages on ash content (%) is shown in Fig. 10. A significant difference ($P<0.05$) was observed in the mean values of ash content (%) at different growth stages. The highest ash content (11.89%) was observed at 8 weeks growth stage. The lowest ash content (7.72%) was observed at 10 weeks growth stage. The ash content (%) was found to increase as follows: 8 weeks > 6 weeks > 4 weeks > 12 weeks > 10 weeks.

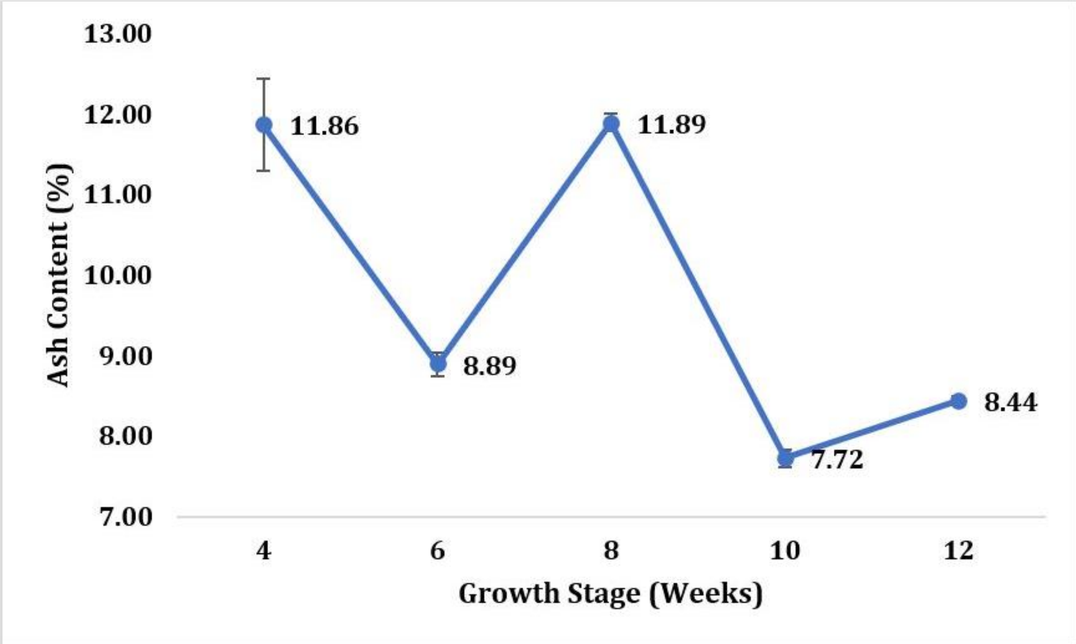

Figure 11: Ash content in different growth stages

Ash content has a marked impact on enhancing the forage quality. Ash means the total mineral content of the forage (Pachamuthu, 2013). According to Hoffman (2005), the normal ash level of corn silage is roughly 5% of dry matter (DM), however, examples have been found with up to 10% ash. The usual ash percentage of total mixed diets, which includes natural minerals, additive minerals, and supplementary minerals, is 9.0% of dry matter. In exceptional circumstances, the ash level of total mixed meals has reached up to 17.0%. Guniea grass harvested after eight weeks contained 11% ash, indicating its viability as a source for silage and total mixed diets in dairy farming.

The three factors affecting forage quality as described in the fact sheet of the United States Department of Agriculture. (2000) are (i). Crude protein and crude fiber, (ii). Plant maturity and the (iii). Plant part. As a plant transforms from its leafy, vegetative stage to its stemmy, reproductive stage, its protein content falls, and its fiber content increases. The leaves are superior to stems because they contain more protein and less fiber. Due to its leafiness, palatability, and high nutritional content, guinea grass cut after 8 weeks would be a suitable feed source for ruminants.

RECOMMENDATIONS AND CONCLUSION/S

This study aimed to analyze the fodder characteristics of guinea grass at various stages of growth. The investigation involved assessing growth parameters and nutrient compositions at different growth stages to determine the optimal harvesting stage for guinea grass as fodder. The results of this study revealed that the pre-anthesis stage or 8-week growth stage (Treatment 3) exhibited superior qualities for harvesting guinea grass, yielding favorable fodder quality. Specifically, this stage demonstrated the highest levels of dry biomass content and fresh biomass content during the pre-anthesis stage, as well as the greatest plant height, number of tillers, number of leaves, ash content, and desirable crude protein and crude fiber content.

Future research directions

Presently, the aforementioned plant is widely acknowledged as an invasive weed within numerous coconut plantations. Drawing upon the outcomes of the conducted experimentation, it is advisable to contemplate utilizing this invasive weed species as a viable fodder option for the livestock situated within coconut plantations, while concurrently implementing efficient management strategies. Conversely, guinea grass holds the potential to serve as an integral constituent in the production of silage.

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EVALUATION OF THE CROWN BUDDING TECHNIQUE ON GROWTH AND YIELD ATTRIBUTES OF HIGH-YIELDING *Hevea* CLONES

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ABSTRACT

Crown budding is a technique that use to replace canopies with undesirable characters in clones but having trunks with high latex yield and timber volumes. The trees produced by crown budding give rise to a three-part-tree ie; seedling rootstock, trunk clone and a crown clone. A crown budding experiment was conducted in 2001 with the selected seven promising clones ie; PR 305, RRIM 717, BPM 24, PB 260, RRIC 121, RRISL 217 and RRIC 130. Different combinations on the tree trunk x crown were compared with control trees without crown budding and pollarded trees eight feet above the bud union. The bud grafting and pollarding processes were carried out on two-year-old plants by using brown budding technique. The girth of the trees was measured annually at 120 cm from the ground level and girth increment was calculated. Tapping was started in all treatment plants in 2006 and the latex yield was recorded from 2006 to 2008 according to the treatments applied in the field. Results of the annual girth increment of trees shown a setback of girth increment of crown budded treatments due to the removal of the canopy when compared to control and pollarded trees of each clone. Control plants that are not bud-grafted with different crowns nor pollarded reached the tapping girth early after 6 years of planting. Similarly trees that are pollarded without crown budded reached a tappable girth one year after control plants whereas trees that crown budded extended their girth increment another one or two years when compared to pollarded or control trees. But in the later stage of 3-5 years back after crown budding, the growth rates of trees are comparable with control trees and crown budded trees with high-yielding clones like RRIC 121 and RRIC 130 showed a higher yield when the growth of trees was compensated with a new canopy structures.

Keywords: Brown budding, Crown clone, Girth, Latex, Three-part-tree

INTRODUCTION

The rubber tree was propagated through rubber seeds during the period of domestication and until the bud grafting technique was developed in 1917 by the Dutch horticulturists in Java. Since then the rubber clones were identified and produced and propagated using base bud grafting methods. The base bud grafting method had many developments over the years starting from ground seedling nurseries to young budding techniques. Since the potential of *Hevea brasiliensis* Müll. Arg. to produce latex depends

on genetic and environmental factors, there are two base budding techniques practiced for the grafting of rubber, identified as "brown budding" and "green budding". The name is given for the color of the budwood used for grafting and accordingly, the age varies. The older technique was the "brown budding" technique where the age of budwood and the rootstock seedling are both about 1-2 years. The green budding, on the other hand, is rather new and at present, almost all buddings are done using this method. In this technique, the age of the seedling rootstock can be as young as 2-4 months. The age of the budwood also can be similar to rootstocks. More than the age, the important criterion is the diameter of the bud wood and the rootstock seedling which are to be similar in size.
Crown budding is not a bud grafting method but it can be performed with either brown or green budding techniques. Also crown budded trees are called three-part trees as there are three parts in the tree*, i.e*. seedling rootstock, stem belonging to one clone, and the crown or the canopy of another clone. Also, as the name implies this method is grafting for the crown and generally, the crown clone is selected to be resistant to diseases or wind damage. Therefore, the usage of crown budding is not common and is always done to add a disease-resistant or wind-resistant canopy. Producing a rubber tree with high yielding trunk and a disease-resistant crown was reported in 1929 at Java. Crown budding was done for high-yielding *Hevea* clones susceptible to Oidium leaf disease with clone LCB 870 which is low yielding but is known to be resistant to this leaf disease (Chandrasekera,1980). Gunaratne, *et al.,* 1984 have discussed the possibilities of reduced wind damage losses, and reduced yield depression during wintering while protecting against leaf diseases of crown-budded trees. There are reports of serious disasters as a result of South American Leaf Blight (SALB) in South America (Yoon, 1973). Crown budding must be used as a plant management method in humid areas to substitute susceptible crowns totally or at least partially. In these 'mixed-crown' plantations, the plants with resistant crowns will serve as a barrier to the dispersal of inoculum and concurrently represent a favorable environment for natural enemies of both pathogens and phytophagous insects.

Crown budding has to be carried out in the field and with the use of ladders or temporary scaffoldings as bud, grafting is done above the tapping panel area i.e. about 8 feet height on the trunk. Therefore, whether to undertake brown budding or green budding is decided by the age of the trees. If the trees are about one year, then green budding can be adopted. But if the trees are older than that then they would be brown budding (Seneviratne, 1997). Also, the maximum age would be about 3 years as even at that age the girth of the trees is about 30 cm and bud grafting on large trees is not only impractical, laborious, and results in low success rates.

In 1985 the clone RRIC 103 which is a high-yielding clone recommended in Group I, got succumb to *Corynespora* leaf disease, and every single tree of clone RRIC 103 available in the country died after repeated defoliation. Similarly, in 1995, the clone RRIC 110, which was recommended in group II got affected by *Corynespora.*

However, unlike base budding, crown budding generally results in a setback with crown clones. However, with the proper technique of budding on green trunk tissue and with the correct trunk-crown combination, such set-back could be avoided (Tan and Leong, 1976).

A crown budding experiment was conducted in Kalutara District under field conditions to evaluate the performance of the crown budding technique on growth and yield attributes of high-yielding Hevea clones.

MATERIALS AND METHODS

A crown budding experiment was conducted in 2001 with the selected seven promising clones *ie;* PR 305, RRIM 717, BPM 24, PB 260, RRIC 121, RRISL 217, and RRIC 130.

Different treatments on the tree trunk and crown combinations are shown in Table 1. In this experiment, the trees of each clone were selected in a field that was established in 1999. Crown budding was done at the age of three years of trunk trees. The treatments were considered as control trees without crown budding, pollarded the canopy of the trees eight feet above the bud union and crown budded in plants (Table 1). Treatments were applied in pairs as in Table 1 and scattered in the field randomly.

Table 1: Treatments of the experiment

Trunk	Crown
PR 305	Control RRIM 717 Pollarded
RRIM 717	Control PR 305 Pollarded
BPM 24	Control PB 260 Pollarded
PB 260	Control BPM 24 Pollarded
RRIC 121	Control RRISL 217 Pollarded
RRISL 217	Control RRIC 121 Pollarded
RRIC 121	Control RRIC 130 Pollarded
RRIC 130	Control RRIC 121 Pollarded

The bud grafting and pollarding processes were carried out on two-year-old plants by using ladders as the brown budding was done above the tapping panel area at about eight feet height on the trunk. The girth of the trees was measured annually at 120 cm from the ground and was taken annually from 2002 to 2014. Tapping was started in all treatment plants in 2006 and the latex yield was recorded in relation to a gram per tree per tapping (g/t/t) from 2006 to 2008 according to the treatments applied in the field.

RESULTS AND DISCUSSION

The mean annual girth of the treated plants was taken one year after treatment was applied (Table 2). Control plants that were not bud-grafted with different crowns nor pollarded reached the tapping girth early in 2006 after 6 years of planting. According to Table 2, it is revealed that trees just pollarded without crown budded also reached a tappable girth one year after control plants whereas trees that crown budded extended their girth increment another one or two years when compared to pollarded or control trees (Table 2).

Table 2: The mean annual girth of the trees

Trt	Trunk	Crown	Annual Mean Girth in Centimeters												
			2002	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**	**2011**	**2012**	**2013**	**2014**
1	PR 305	Control	16.9	28.8	41.6	45.2	47.4	50.2	51.9	53.1	54.2	54.5	55.9	55.7	56.4
		RRIM 717	18.3	19.8	30.0	34.9	36.9	41.7	42.6	44.5	49.3	50.5	50.5	52.6	52.7
		Pollarded	16.8	27.8	41.2	45.6	46.5	49.8	50.4	50.8	52.0	53.7	54.2	55.1	55.7
2	RRIM 717	Control	17.8	29.4	42.1	47.3	48.4	51.4	52.5	53.5	55.4	56.4	56.8	57.8	58.0
		PR 305	17.8	19.8	30.1	34.3	36.7	40.0	40.9	42.7	46.3	46.8	48.0	51.3	52.2
		Pollarded	17.1	26.7	37.4	43.6	44.7	46.8	50.0	51.5	55.5	56.2	56.3	57.2	54.5
3	BPM 24	Control	17.8	28.3	38.4	45.8	46.1	48.2	49.1	49.6	49.6	52.0	53.8	54.2	54.2
		PB 260	16.5	18.0		33.5		47.0	48.0	50.4	57.0	60.4	66.4	.	.
		Pollarded	16.8	25.1	34.3	40.1	41.8	43.4	45.1	46.5	47.7	48.5	48.7	51.2	52.8
4	PB 260	Control	19.6	31.7	44.5	51.1	51.8	55.1	57.6	57.8	63.3	64.4	65.4	64.5	65.5
		BPM 24	18.1	20.0	30.0	38.2	39.9	45.2	46.9	48.3	52.8	54.6	55.4	55.3	53.5
		Pollarded	17.4	29.0	42.8	47.0	51.0	52.0	52.7	54.0	57.3	57.3	60.8	61.5	63.0
5	RRIC 121	Control	21.2	33.0	47.6	55.1	55.8	56.3	63.6	64.9	69.6	70.7	74.3	72.1	77.7
		RRISL 217	21.9	23.1	33.8	39.8	44.3	46.9	49.1	50.8	53.7	54.5	54.9	53.7	55.5
		Pollarded	18.0	28.4	42.3	50.7	53.2	49.1	61.6	63.2	68.2	69.8	71.4	74.3	74.6
6	RRISL 217	Control	19.9	31.1	43.2	49.4	51.0	60.4	57.3	58.4	61.4	62.9	62.2	63.2	67.1
		RRIC 121	20.5	22.8	35.3	40.8	42.6	47.4	50.2	51.2	53.5	54.7	55.1	55.7	58.5

		Pollarded	17.7	27.7	40.2	45.0	46.4	57.0	51.9	53.0	55.2	57.4	58.1	59.1	59.7
7	RRIC 121	Control	21.1	32.9	47.3	54.2	55.4	55.8	59.6	60.4	63.1	63.7	64.9	66.1	66.6
		RRIC 130	24.2	24.5	29.5	34.5	36.9	51.1	52.1	52.9	55.9	57.9	58.9	59.0	60.0
		Pollarded	22.7	34.5	48.3	54.6	56.5	53.5	64.6	65.6	68.5	69.4	69.1	70.8	68.9
8	RRIC 130	Control	21.7	34.4	49.0	52.4	54.4	57.2	56.5	57.4	58.3	58.9	60.3	61.4	63.6
		RRIC 121	21.5	22.6	32.0	38.5	55.1	42.7	44.5	45.8	49.8	50.8	44.1	61.5	61.5
		Pollarded	22.1	34.0	46.4	51.6	53.8	62.2	54.7	55.8	57.4	58.0	58.4	58.8	59.2

In Table 3, the annual girth increment is tabulated with the initial girth and until plants reached their tappable girth in 2006.

Table 3: Initial girth and girth increment of the trees in centimeters

Trt	Trunk	Crown	Year				
			2002	2003	2004	2005	2006
1	PR 305	Control	16.8	11.9	12.8	3.6	2.2
		RRIM 717	18.2	1.6	10.1	4.9	2.0
		Pollarded	16.8	11.1	13.4	4.3	1.0
2	RRIM 717	Control	17.8	11.6	12.7	5.3	1.1
		PR 305	17.8	2.0	10.3	4.2	2.4
		Pollarded	17.0	9.7	10.7	6.2	1.1
3	BPM 24	Control	17.8	10.5	10.2	7.3	0.3
		PB 260	16.5	1.5	5.5	10.0	4.5
		Pollarded	16.8	8.3	9.2	5.8	1.7
4	PB 260	Control	19.6	12.0	12.8	6.6	0.7
		BPM 24	18.1	1.9	10.0	8.2	1.7
		Pollarded	17.4	11.6	13.8	4.2	4.0
5	RRIC 121	Control	21.2	11.8	14.6	7.5	1.6
		RRISL 217	21.9	1.2	10.6	6.1	4.5
		Pollarded	18.0	10.4	13.9	8.4	2.5
6	RRISL 217	Control	19.9	11.2	12.1	6.2	1.6
		RRIC 121	20.5	2.3	12.5	5.5	1.8
		Pollarded	17.7	10.1	12.5	4.8	1.4
7	RRIC 121	Control	21.1	11.8	14.3	6.9	1.2
		RRIC 130	24.2	0.33	5.00	5.00	2.36
		Pollarded	22.7	11.8	13.8	6.4	1.8
8	RRIC 130	Control	21.7	12.7	14.6	3.4	2.0
		RRIC 121	21.5	1.1	9.4	6.5	5.5
		Pollarded	22.1	11.8	12.5	5.2	2.2

According to Table 3, it is shown the growth of plants that are control trees following a normal girth increment of 10 cm each year. However, it was revealed that plants that pollarded or crown budded resulted in a setback of girth increment due to the removal of the canopy. As seen in Table 3 in the later stage of 3-5 years back after crown budding, the growth rates of trees which are pollarded and crown budded are comparable with control trees. But according to Table 3, growth rates of the trunk x crown combination of different clones differed with each clonal combination. For an example, the highest trunk x crown combination is recorded by stem clones which were crown budded with RRIC 121. Pollarding trees at a disease condition was also evaluated in this experiment and has shown that there was slight decrease in growth but recovered later at the tappable age (Table 3). According to Chandrasekera (1980), results reported for the crown clone, LCB 870 which was low yielding but resistant to leaf disease *Oidium*. There this crown indicated a setback to growth initially for a period of more than two years and after that, it was developed it's crown for giving a sufficient photosynthetic area that resulted in a growth rate equivalent to control trees.

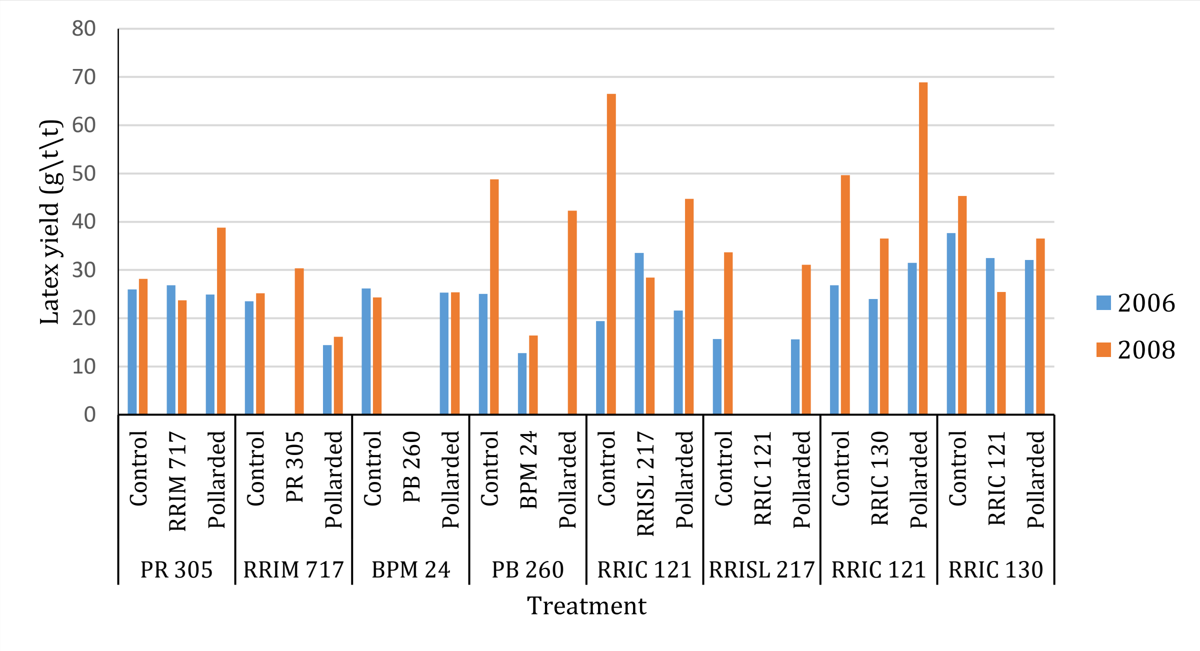

Figure 1: Mean annual yield variation of different treatments

As shown in Fig. 1, the highest mean g/t/t values are varied with the clone concerning high yielding to low yielding. Pollarded trees in most of the clones tested ie; PB 260, RRIC 121, and RRIC 130 recorded comparably higher latex yields. When the trees were crown budded trees with high-yielding clones like RRIC 121 and 130 showed a higher yield when the growth of trees was compensated with a new canopy structure. As reported by Chandrasekera (1980) crown budding with clone LCB 870 has resulted in a setback to growth by approximately two years and an average yield depression of 31.58 percent during the first four years in tapping. Generated knowledge of trunk clones of different clones crown budded with high yielding clones could be able to enhance canopy structure for giving high a photosynthetic area for food assimilations higher yields.

RECOMMENDATIONS AND CONCLUSION/S

The highest mean annual girth was recorded in the crown of the tree budded with RRIC 121. Pollarding trunk canopy at leaf diseases can also be considered as a remedial measure to survival of disease conditions. But it is negatively impacted on latex yield and growth performance of high yielding clones. Further, crown budding with high-yielding clones ie; RRIC 121 and RRIC 130 would enhance the growth performance and the yield at a greater level when compare the all-other clones tested.

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Technical Session IV

"Integrated Management and Policy Implications in Plantation Industry"

***Lead Presentation Delivered by*;**

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Dean (Horticulture)

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Tamil Nadu Agricultural University

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STAKEHOLDER'S SATISFACTION ON THE CONVERSION OF SRI LANKAN TRADITIONAL TEA AUCTION INTO AN E-AUCTION

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ABSTRACT

Sri Lanka is a known source of finest tea in the world. The COVID-19 pandemic encouraged transformation of the out-cry tea auction into a virtual platform. However, an in-depth study on the benefits and drawbacks of this transformation process, as well as the stakeholders' satisfaction with it, was not adequately investigated. This study evaluates the level of satisfaction of the stakeholders involved in the tea auctioning process on this transformation and its benefits and drawbacks. The research was carried out at John Keells PLC, one of the country's leading tea brokers which has the largest warehousing complex and network in the tea trade. A stratified sampling technique was used to collect 75 stakeholders who are directly and indirectly connected with the E-auction. A pre-tested survey instrument validated by applying a reliability test was administrated to collect data on perceived ease of use, usefulness, usability, socio-economic factors, and industry-related factors. The SWOT analysis was undertaken using collected data and the results revealed that the newly implemented E-auction has many strengths and opportunities compared to out-cry tea auction. These findings were further confirmed by the establishment of a relationship among stakeholder satisfaction and independent variables by application of the ordinal logistic regression model. The descriptive analysis results revealed that the degree of stakeholders' satisfaction with the transformation process varied in the range of high, moderate, and low, with values of 45.33%, 49.33%, and 5.33%, respectively. According to the ordinal logistic regression results, the overall model was significant ($P<0.05$), and the results exhibited that stakeholder satisfaction was positively correlated with experience, age, perceived ease of use, and usefulness, whilst it was negatively correlated with education level, usability, and stakeholder type. The results of this study provide sufficient evidence that the newly deployed E-auction has advantages and disadvantages over the conventional auction and relevant authorities should take suitable actions to improve the E-auction system's performance with the technological advancements.

Keywords: Conventional, Covid-19, E-auction, Satisfaction, Stakeholders, SWOT Analysis

INTRODUCTION

Given its recognition as a prominent producer of the world's excellent teas, "Ceylon Tea" demands a premium place on the global market. The Sri Lankan tea sector has a long history and has played an integral part in the country's economic development. The tea industry in Sri Lanka contributes significantly to the foreign exchange earnings and employment in our country's economy (Arachchige, 2020).

Background

Sri Lanka remains as the 4th largest tea producer and the 2nd largest tea exporter in the world in 2021 (Tea Exporters Association Sri Lanka, n.d.). The Colombo Tea Auction (CTA) is the world's largest tea auction center, dealing with more than three hundred million kg of black tea every year (Annual Report 2016, n.d.). The Colombo Tea Traders Association (CTTA) holds auctions as per the Sri Lanka Tea Board's (SLTB) by-laws and conditions of sale to maintain a regular, stable, and legal manner of selling tea (Athukorala, 2020).

The auction procedure had been carried out manually for a long time and had numerous problems, such as being time-consuming, and difficulties faced on updating with technical advancements. The concept of transforming into an E-auction was taken from time to time by John Keells PLC integrated with Mobitel "E-gavel application-2013" and "m-auction-2015". For several years, the notion of an "Electronic tea auction" was put on hold. The main reason for not continuing such transformation was the fear of losing the current physical bid (John Keells Innovates Electronic Tea Auction System with Mobitel | Daily FT, n.d.). Due to imposed health guidelines for mitigation of the spreading COVID-19 pandemic in 2020, the Colombo tea auction could not be held continuously for two weeks. As a solution, the CTTA decided to shift from the out-cry auction system into an E-auction platform with the assistance of the SLTB and EDB aiming to improve its productivity, effectiveness, and efficiency with technological enhancement (Athukorala, 2020).

Research Problem

The traditional outcry auction system in Sri Lanka is difficult to sustain due to its inconvenient nature. Efforts to computerize the auction were unsuccessful until the COVID-19 pandemic. To overcome travel restrictions and health guidelines, the Sri Lankan tea industry transformed the auction into an E-auction. The first E-auction was held on April 4th, 2020, after resolving technical issues. However, no studies have assessed stakeholder satisfaction with the new process. This study aims to evaluate stakeholder satisfaction with the transformation of the Sri Lankan tea auction into an E-auction.

Objective(s)

General Objective:

To analyze the degree of satisfaction of supply chain stakeholders on the transformation of Sri Lankan conventional tea auction into an E-tea auction.

Specific Objectives:

- To compare the conventional tea auction with the E-tea auction
- To determine strengths, weaknesses, opportunities, and threats of the existing E-tea auction
- To make suggestions on further improvement of the existing E-tea auction

MATERIALS AND METHODS

Conceptual framework

This study aimed to evaluate stakeholder satisfaction with the transformation of the Sri Lankan tea auction into an E-auction, using the Technology Acceptance Model (TAM) as the conceptual framework. The TAM considers factors such as perceived usefulness (PU), perceived ease of use (PEU), usability (US), and enterprise-related and socio-economic factors in determining user satisfaction with enterprise resource planning (ERP) systems (Davis & Venkatesh, 2004). By applying this framework, we sought to examine the relationship between stakeholder satisfaction and variables impacting the conversion from an outcry to an E-auction, filling a knowledge gap in understanding stakeholder satisfaction. This insight is crucial for the Sri Lankan tea industry to overcome challenges posed by the COVID-19 pandemic (Fig. 1).

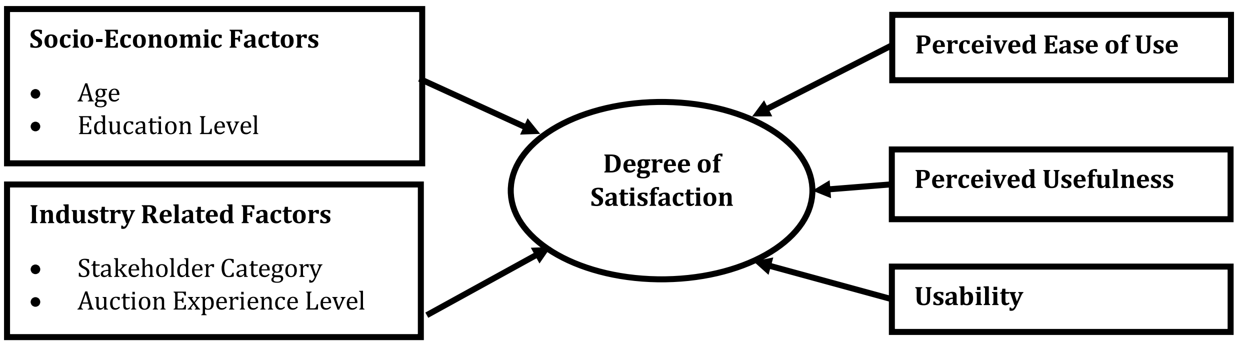

Figure 1: Conceptual Framework for the Study

Source: (Davis & Venkatesh, 2004), (Ha & Stoel, 2008)

Sampling method:

The study was done at John Keells PLC, one of the foremost tea brokers in Sri Lanka with the biggest tea warehouse complex. Seventy-five stakeholders who are directly and indirectly involved with the E-auction were selected using a stratified purposive sampling technique, as shown in the (Hsu, 2009). Out of six stakeholder groups, five main stakeholders' groups except tea manufactures are directly involving auction process and therefore comparatively higher number of personals representing top and medium management, and operational level officials were selected for data collection. This arrangement was purposely done to gather more realistic information from diverse group of direct stakeholders (Table 1).

Table 1: Research Sample

SLTB registered Stakeholders	Auction organizer	Manufacturers	Exporters & Buyers	Brokers	Warehouse keepers	Auction observer indirect
Population 992	1	686 High -157 Medium -142 Low -387	288 Large -7 Medium-77 Small -204	8	8	1
Sample 100 (10%)	Governors Committee-1 Steering-committee –1 CTTA-officials-3	(RPC/Privet factories) High -7 Medium -6 Low -17	Large -5 Medium-10 Small -15	Large - 10 Medium-5 Small -5	Warehouse for brokers-10	Tea Board Officials-5
	Subtotal 5	Subtotal 30	Subtotal 30	Subtotal 20	Subtotal 10	Subtotal 5

Data Collection and Analysis

The tea auction stakeholders were surveyed using a pretested questionnaire and focus group interviews. Internal and external secondary data were gathered from John Keells PLC and the Sri Lanka Tea Board database. A SWOT analysis was conducted to identify strengths, opportunities, threats, and weaknesses of the digital auction system. The SWOT analysis results were validated through correlation and regression analysis. The relationship between satisfaction in the transformation process and independent variables (Table 2) was analyzed using descriptive analysis and an ordinal logistic regression model. The effect of independent variables (Perceived Ease of Use, Perceived Usefulness, and Usability) on satisfaction was measured using a 5-point Likert scale, scoring system, and indexes (Chandra *et al.,* 2018).

Table 2: Independent variables and their unit of measurements

Independent Variable	Definition	Unit of Measurement
X1	Socio-Economic Factors-	
	Age	Years
	Education	Years
X2	Industry-related Factors-	
	Stakeholder category (broker, manufacturer, buyer, warehouse keeper, auction organizer, SLTB)	Dummy variable
	Involvement with the auction (experience)	Years
X3	Perceived Usefulness (Performance attributes and New Features)	Likert scale
X4	Perceived Ease of Use (E-auction benefits and strengths)	Likert scale
X5	Usability (Weaknesses and threats of E-auction)	Likert scale

Equation 1: Index Scale of Measurement

$$\text{Index (PEU,PU,US)} = \frac{\text{Marks achieved by the Stakeholder}}{\text{Total Potential Mark}} \times 100$$

Qualitative data were collected with the assistance of Likert scales and dummy variables. The percentage will be used to determine the level of satisfaction for each category of satisfaction level (Gunathilaka & Rathnayaka, 2012; Table 3).

Table 3: Likert Scale Measurements

Component	Likert Scale Measurement	Ranking
Strongly disagree	1	Less satisfied
Disagree	2	Moderately satisfied
Neither agree nor disagree	3	
Agree	4	highly satisfied
Strongly Agree	5	

To assess the level of variation and correlations between the test parameters, descriptive analysis and regression analysis were used. The link between the dependent variable (Y-Degree of Satisfaction), which has a meaningful order of high-2, medium-1, and low-0, and the other variables, was explained by an ordinal logistic regression model.

Empirical Model:

In order to determine the link between the dependent and independent variables, an empirical model was created for the study.

Equation 2: Empirical Model Equation for the Study

$$\boldsymbol{SL\ (pred.) = \beta 0\ + \beta 1(X1)\ + \beta 2(X2)\ + \beta 3(X3)\ + \beta 4(X4)\ + \beta 5(X5)\ + \beta 6(X6)\ + \beta 7(X7)\ + \beta 8(X8)\ +\ \varepsilon}$$

Where,

SL-Satisfaction Level; $\boldsymbol{\beta 0}$- Coefficient of Constant; X1- Age (AG); X2-Experience (EX); X3-Education Level2(EUL2); X4-Education Level3(EUL3); X5-Stakeholder type (ST); X6-Perceived Usefulness (PU); X7-Perceived Ease of Use (PEU); X8-Usability (US); $\boldsymbol{\varepsilon}$- Error

The hypothesis tested were as follows. The H0 was rejected if the P value < 0.05.

H0 – There is no relationship between the degree of satisfaction with the transformation of conventional tea auctions into E-tea auctions and the independent variable.

H1 – There is a relationship between the degree of satisfaction with the transformation of conventional tea auctions into E-tea auctions and the independent variable.

RESULTS AND DISCUSSION

This section summarizes the reliability statistics, SWOT analysis, descriptive statistics of the data, regression analysis and the outcome of the empirical model used to analyze the data.

Reliability test

The pretested survey instrument demonstrated strong internal consistency with a Cronbach alpha value of 0.955 for the overall tool. Sub-components such as perceived ease of use, usefulness, and usability also exhibited high reliability (Table 4). The overall instrument had a significance level of P<0.001 and alpha values of 0.933, 0.817, and 0.948 for perceived ease of use, usefulness, and usability, respectively. These findings confirm that the research instruments were reliable and would yield accurate outcomes.

Table 4: Reliability Statistics for Overall and Independent Variable Instrument Tool

Item	No of Items	Cronbach's Alpha	Significant value
Overall instrument tool	74	0.955	.000
Perceived ease of use	13	0.933	.000
Perceived usefulness	17	0.817	.005
Usability	13	0.948	.000

SWOT analysis

Strengths of the E-Auction

The ability of producers to monitor market trends online while seated at their rural tea estates via the internet might be considered one of the system's primary assets, along with improving technological literacy (Table 5).

Table 5: Strengths of the E-auction

Strengths		Total Score	Weightage	Ranking
S1	Producers can keep an eye on the market trends online	325	0.1238	1
S2	Improve the technology literacy	325	0.1238	1
S3	Ensure reliability	318	0.1211	2
S4	Higher level of compatibility	317	0.1208	3
S5	Reduce/eliminate duplication of data entry	313	0.1189	4
S6	Receive real-time market information	312	0.1192	5
S7	Reasonable time for biding any lot in this system	305	0.1162	6

According to the weighting, providing reliability and a greater level of compatibility was listed as the 2nd and 3rd levels of strengths. Manufacturers will also benefit since they can study the tea market and subsequently have an idea of the price, they received for the tea that they produced, in addition to buyers and brokers. Currently, 6.5 lots are sold on an average per minute. The countdown begins at 9 seconds, and it will end within 4 seconds, just as customers begin to bid. Each buyer thus has a significant period of time to place a bid on a particular lot. Participants will also obtain real-time market reports (Fig. 2).

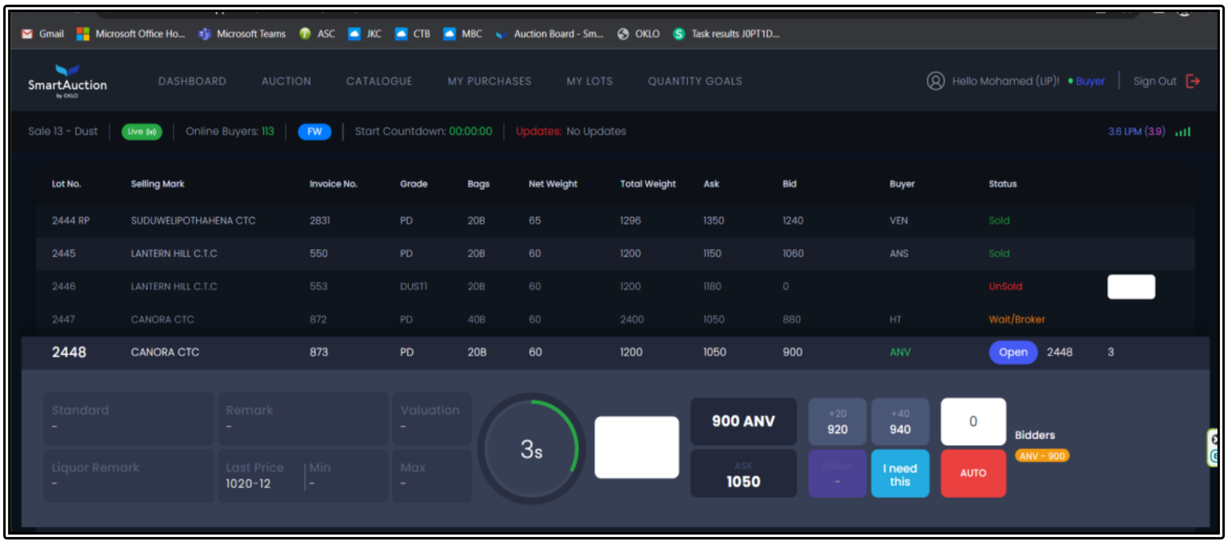

Figure 2: "OKLO" E-Auction Interface

There is no data duplication because every piece of information is entered into the system. E-auction is more reliable than traditional auction systems since all data is systematic. Thus, it can be said that the aforementioned elements make the E-auction system stronger.

Weaknesses of the E-Auction

The (Table 6) indicates that the physical interaction between buyers and sellers was what

Figure 2: Interface of the E-auction System

helped traditional tea auction endure for such a long time. As a result, one of the main weaknesses of the online system can be highlighted as the loss of physical interaction between stakeholders. Another biggest weakness was the stakeholders' lack of online competency, which made them more likely to reject the system as they became mentally exhausted from adjusting to a brand-new one.

Table 6: Weaknesses of the E-auction

	Weaknesses	Score	Weightage	Ranking
W1	Less interaction among buyers and sellers	306	0.136	1
W2	Not fully automated system	291	0.129	2
W3	Not a good system for people who have technological barriers	283	0.126	3
W4	Creates more opportunities for large and medium buyers	255	0.113	4
W5	Mental tiredness	250	0.111	5
W6	Low bidding efficiency	212	0.094	6

Opportunities of the E-Auction

According to (Table 7), the E-auction system's greatest opportunity was its viability as an alternative during the COVID-19 pandemic. With the curfew and social distancing measures in place, the traditional Sri Lankan tea auction couldn't operate for two consecutive weeks, leaving no other option but to transition to an E-auction. Additionally, the E-auction system enables easier analysis of the tea market as market reports are available post-sale. Unlike the previous system dominated by large-scale buyers, the E-auction system offers equal bidding chances to all buyers, making it favorable for newcomers. In summary, the E-auction process effectively capitalizes on opportunities.

Table 7: Opportunities and Threats of the E-auction

Opportunities		Total Score	Weightage	Ranking
O1	Good alternative during the pandemic	344	0.153	1
O2	The ease of analyzing the tea market	322	0.143	2
O3	Buyers' equality in the system	306	0.136	3
O4	To expose for foreign buyers (price up US dollar)	296	0.132	4
O5	Good opportunity for newcomers	282	0.125	5
O6	To open up new market avenues	261	0.116	6

Threats of the E-Auction

The major threats identified in (Table 8) include continuous power failure in the country and the potential loss of personal selling skills. The traditional art of selling tea at the Colombo out-cry auction relied on the expertise of brokers, but as the system transitions online, there is a risk of skill erosion and limited opportunities for newcomers to practice. Furthermore, technological advancements may lead to modifications that reduce the need for intermediaries in tea sales. To address these threats, collaborative efforts between CTTA, SLTB, and EDB are essential in implementing effective solutions.

Table 8: Threats of the E-auction

	Threats	Total Score	Weightage	Ranking
T1	Continuous power failure in the country	296	0.158	1
T2	Losing one's skills	290	0.155	2
T3	Expose foreign markets (increase competition)	283	0.151	3
T4	Direct purchasing without many intermediaries	271	0.145	4
T5	Handling both buyers' and brokers' valuation details can lead to privacy issues	259	0.138	5

Comparison of Conventional Auction and E-Auction

It has mentioned stakeholder’s agreement as a percentage on each given statement.

Comparison of Benefits

The lack of physical interaction between buyers and sellers is a drawback of the E-auction system compared to the conventional auction. In the traditional system, gestures like nodding or winking allowed for more interaction. However, the E-auction system proves effective in all other dimensions and has been confirmed as an efficient alternative (Kadavil, 2007). Real-time information provides buyers with market status updates before, during, and after the auction, enhancing its effectiveness (Tiwana, 1998; Table 9).

Table 9: Benefits Comparison between out-cry Auction and E-Auction

Conventional auction benefits	D %	N %	A %	E-auction benefits	D %	N %	A %
The gesture can observe	05	04	91	Quick access to information	01	04	95
Ensure a free and fair competition	06	12	82	Real-time updating dashboard	01	09	90
Giving producers a large marketing platform	06	12	82	Time-Saving	01	09	89
Buyers can watch the operations of their competitors	06	15	80	Reduction of operational cost	03	08	89
More interaction among brokers and buyers	10	13	78	Ability to log in at any given time	0	13	87
More trustfulness	05	36	59	High transparency	04	15	82

D%- Disagreement N%- Neither agree nor Disagree A%- Agreement

Comparison of Defects

The main drawback of the out-cry auction was its inability to operate during the COVID-19 outbreak, leading to a two-week closure (Table 10). Implementing the E-auction system became the only solution for continuous functioning of the Sri Lankan tea auction with a history of over 150 years. Compared to the conventional auction, the E-auction has minimal defects (Kadavil, 2007). Initially, low IT literacy and technical barriers posed challenges, but stakeholders have adapted to the user-friendly features and benefits of the E-auction. There is a willingness to enhance the infrastructure further, making it an even more effective and user-friendly system.

Table 10: Defects Comparison between Out-cry Auction and E-Auction

Conventional auction defects	D%	N%	A%	E-auction defects	D%	N%	A%
Unable to hold due to covid-19 pandemic limitations	05	05	89	Less interaction among buyers and sellers	04	20	76
Unavailability of previous bid history	08	16	76	Not a good system for those who have technological barriers	08	17	75
Less transparency	11	15	74	Not fully automated	04	25	60
Big buyers dominating	12	15	74	More opportunities for large and medium buyers	20	28	52
Prone to human errors	15	17	68	Mental tiredness	09	53	37
Not an effective for newcomers	15	33	52	Low bidding efficiency	38	25	37

D%- Disagreement N%- Neither agree nor Disagree A%- Agreement

The results that have been taken from SWOT analysis and comparison were confirmed by using the descriptive, and ordinal logistic regression analysis.

Descriptive Analysis

Results of the descriptive analysis showed that respondents' ages ranged from 22 to 66, with a mean age of 36 years (Table 11). The average stakeholder experience in the tea business is 10 years, with 1 and 58 years, being the minimum and maximum.

Table 11: Descriptive Analysis Results

Variable	Mean	Min	Max
Level of Satisfaction	1.40	0	2
Age	36.33	22	66
Experience	10.12	1	58

Overall Satisfaction of the Stakeholders

The research found that, correspondingly, 45.33%, 49.33%, and 5.33% of stakeholders are highly, moderately, and less satisfied with the conversion to the electronic auction (Table 12).

Table 12: Stakeholder Satisfaction Percentage

Level of Satisfaction	Frequency	Percentage
0	04	05.33
1	37	49.33
2	34	45.33
Total	75	100.00

Source: STATA output

Correlation and Regression Analysis

The association between the level of satisfaction with independent factors (Social and economic variables, factors relating to industry, PEU, PU, US) was evaluated using correlation analysis. There is a positive correlation between level of satisfaction and education level, online handling literacy, PU, PEU and US while having a negative correlation with stakeholder type, age, and tea industry experience (Table 13).

Table 13: Correlation Analysis Results

Independent Variable	satisfaction level		
	Pearson Correlation	**Sig. (2-tailed)**	**Interpretation**
Stakeholder Type(direct/indirect)	-0.329**	0.004	Weak (-) correlation
Age	-0.102	0.383	Very weak (-)correlation
Education Level	0.050	0.667	Very weak (+)correlation
Tea Industry Experience	-0.182	0.118	Very weak (-)correlation
Online handling Literacy	0.398**	0.000	Weak (+) correlation
PU	0.747**	0.000	Strong (+)correlation
PEU	0.820**	0.000	Very Strong (+)correlation
US	0.255*	0.027	Weak (+) correlation

** Correlation is significant at the 0.01 level (2-tailed).

* Correlation is significant at the 0.05 level (2-tailed)

The regression model used in this study was an ordered logistic regression model, and it was taken from the related study (Kishokanthan, 2014).

Table 14: Ordinal Logistic Regression Results

Component (Log likelihood = -21.349354)	Ordered Logistic Regression Results
Number of observation	75.00
LR chi2(8)	86.83
Prob > X_2	0.0000
Pseudo R^2	0.6704

The Prob > X_2 value is 0.000, which is less than the 0.05 significance level in the model summary, showing that the regression model as a whole fit significantly at a 95% confidence level. Pseudo-R square for the calculated model is 0.6704. Accordingly, R square indicates that eight independent variables in the model account for 67.04% of the variance in satisfaction level resulting from the conversion of a traditional auction into an electronic auction(Table 14). The above independent variables have a positive or negative association with the degree of satisfaction level. Meanwhile, only the estimated perceived ease of use variable has a significant positive relationship with the degree of satisfaction level (Table 15).

Table 15: Coefficient Results

Level of Satisfaction	Coefficient	P value
Age	0.07	0.26
Eul2	-1.33	0.25
Eul3	-0.11	0.95
Stakeholder type	-1.23	0.28
Experience	0.02	0.81
PU	0.01	0.87
PEU	0.38	0.00
US	-0.05	0.42

Equation 3: Final Empirical Model Equation for the Study

$$\boldsymbol{SL = \beta 0 + 0.06AG - 1.3Eul2 - 0.11\, Eul3 - 1.23\, ST + 0.02EX + 0.01PU}$$
$$\boldsymbol{+0.38PEU - 0.05\, US + \varepsilon}$$

Predicted Probabilities Results-Margins

The likelihood changes as the predictor or independent variable is increased by one unit, as shown by marginal effects. As a result, the following explanation can be used to explain predicted probabilities for satisfaction levels of "0" (least satisfied), "1" (moderately satisfied), and "2" (most satisfied).

Table 16: Average Marginal Effect (AME) Results for "0, 1, and 2" Satisfaction Level

Independent Variable	("0" Satisfaction Level)	("1" Satisfaction Level)	("2" Satisfaction Level)
Age	-0.0009	-0.0038	0.0047
Eul1	-0.0014	-0.0060	0.0074
Eul2	0.0167	0.0691	-0.0858
Eul3	0.0000	0.0000	0.0000
Stakeholder type	0.0168	0.0695	-0.0863
Experience	-0.0002	-0.0009	0.0011
PU	-0.0002	-0.0007	0.0008
PEU	-0.0051**	-0.0213***	0.0264***
US	0.0007	0.0028	-0.0034

Source: STATA output

Age of the Stakeholders: Given that all other model variables are held constant, the likelihood changes as a unit gets older by 0.0009 at a less satisfying level, 0.0038 at a moderately satisfying level, and 0.0047 at a highly satisfying level. The similar interpretation may be made for all other factors as well (Table 16).

Younger stakeholders, who have better ICT literacy abilities, are more likely to support the conversion of traditional tea auctions to electronic auctions than stakeholders in the middle and older age groups. Therefore, at the least satisfactory level, the marginal values are -0.09%, at the moderately satisfying level, -0.38%, and at the highly satisfying level, 0.47%.

Education Levels 1 and 2 of the Stakeholders: Eul1 (-0.14%), (-0.6%), and Eul2 (1.67%, 6.911%) at the levels of satisfaction that are less and moderately satisfied, respectively. Because of their limited ICT literacy and lack of usage of modern technologies, stakeholders with less advanced educational backgrounds (Advanced level) are unlikely to participate in this transition. Therefore, they might not be happy with the transformation described above. The probability of these stakeholders benefiting from this transformation are significantly higher if they have a strong educational background (graduate or postgraduate). Consequently, it has favorable marginal values.

Stakeholder Type: For levels of less satisfied, moderately satisfied, and very satisfied, the marginal values for the type of stakeholder are, respectively, 0.17%, 0.69%), and -0.86%. The majority of respondents were buyers and manufacturers, and because of the aforementioned restrictions, it's possible that they weren't satisfied with the E-auctioning procedure.

Stakeholders' past experiences: Less satisfied, moderately satisfied, and extremely satisfied levels' marginal experience values are (-0.02%), (-0.09%), and 0.11%, respectively. Stakeholders who are more familiar with the limitations of conventional auctions would prefer a new approach that is more practical and efficient for them. However, the research done by (Kishokanthan, 2014) showed that there is a bad correlation between stakeholder experience and level of satisfaction. The COVID-19 pandemic did not commence until 2014, when this study was conducted. Due to the loss of current physical bidding, the knowledgeable stakeholders who were aware of the limitations also tended to the traditional auction.

Perceived Usefulness: Stakeholders are more inclined to adopt new features of the E-auction system and performance attributes that are considered to be useful. As a result, it has a positive marginal value at a very satisfactory level. For less satisfied, moderately satisfied, and highly satisfied levels, the marginal values for PU are (-0.02%), (-0.07%), and 0.08%, respectively. These findings confirm an earlier study made by (Daud *et al.,* 2018). It confirmed that user satisfaction has a positive correlation with perceived ease of use.

The perceived ease of use of the E-auction process explains its strengths and benefits. For less, moderate, and high levels of satisfaction, it has marginal values of (-0.51%), (-2.13%), and (2.64%) respectively. The stakeholders are more like the E-auction process' advantages and strengths. They might have been very pleased with this alteration as a result.

Usability: The process of an E-auction faces both strengths and limitations. As a result, stakeholders have a low likelihood of usability at a highly satisfactory level and given recent advancements in technology they are searching for an auction system that is more user-friendly.

RECOMMENDATIONS AND CONCLUSION/S

The study concluded most of the stakeholders are moderately satisfied (49.3%) with the transformation of conventional auctions into E-Auction, whilst others are highly (45.3%) and less satisfied. (5.3%).

The model's findings confirmed that stakeholder satisfaction was positively connected with experience, age, perceived ease, and usefulness but negatively correlated with stakeholder type, education level, and usability. Perceived Ease of Use of the E-Auction system is statistically significant with a degree of satisfaction on the transformation of conventional auctions into E-Auction.

According to the SWOT analysis, the strengths of the transformation of E-auction; the availability of real-time market information, reduction/elimination of duplication of data entry, and easy prediction of the market trends due to the online visibility of information even tea producers located in remote tea estates. The opportunities exhibited as the alternative viable mechanism to overcome the constraints occurred due to the COVID pandemic situation.

E-auction creates benefits such as the ability to log in at any given time, maintaining high transparency, time-saving, reduction of operational cost, and real-time updating dashboard. E-auction systems also create some defects such as less interaction among buyers and sellers, not fully automated current system, not a good system for people who have low IT literacy, etc.

Hence, this study provides sufficient evidence that the newly deployed E-auction has advantages and disadvantages over a conventional auction and relevant authorities should take suitable auction strategies to improve the system's performance with the technology advancements.

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EVALUATION OF THE EFFECTIVENESS OF THE FARMER FIELD SCHOOL EXTENSION APPROACH FOR THE DISSEMINATION OF TEA TECHNOLOGY TO TEA SMALLHOLDERS IN KANDY DISTRICT

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ABSTRACT

Despite having a prominent position in Sri Lanka's tea sector, smallholders confront numerous challenges, including a lack of technology, a shortage of skilled workers and inputs, low productivity, high production costs, etc. This study seeks to assess the effectiveness of the Farmer Field School (FFS) extension technique to improve the adoption rate of cultural practices toward boosting tea smallholdings' land productivity and profitability in the search for an extension approach to address the aforementioned challenges. In four Grama Niladhari Divisions in the Kandy district, the stratified purposive selection technique was used to select 50 tea smallholders who take part in FFS programs and an additional 50 farmers who had not attended the same programs (NFFS Group). A cross-sectional field survey using a pretested survey instrument and validated its internal consistency by applying a reliability test. Descriptive analysis, hypothesis testing, and an ordered logistic regression model were used to explain the association between the variables, which were measured using a scoring system, 5-point Likert scales, and indexes. The result shows there was a significant difference between FFS and NFFS tea smallholders in the adoption of agricultural practices ($t = 3.362$, $p < 0.001$), the productivity of land ($t = 1.991$, $p < 0.05$), and cost of production ($t = -3.976$, $p < 0.001$. The ordered logistic regres[1]sion model is fitted significantly ($P < 0.05$). The R square of the model indicates that, according to the chosen independent variables, 59.94% of the variance in adoption level considerably enhanced the recommended cultural practices. This study proved that the FFS approach is a platform for agricultural innovation and information dissemination for enhancing farmers' knowledge and modifying their attitudes toward the adoption of cultivation practices in order to increase the land productivity and profitability of smallholdings' land productivity, and it demonstrated the need for policymakers to give it consideration for implementation across the sector.

Keywords: Adoption, Effectiveness, Farmer field school, Kandy district, Tea smallholders

INTRODUCTION

The delicious ingredient of *Camellia Sinensis* plant leaves composes the world's most popular beverage apart from water. Tea's global demand has remained stable for a long time. More than a century, the tea industry has been a key contributor to Sri Lanka's economy in terms of foreign exchange earnings, national output, and employment for more than a century. In the year 2021, 285,867 MTs of tea were exported, and USD 1.32 billion in export revenue was earned ("Pure Ceylon Tea from Sri Lanka", 2022).

Background

In Sri Lanka, under the Tea Control Act. tea smallholdings are classified as land areas of less than 10 acres (4 hectares) (Wekumbura, *et al.*, 2017). Tea smallholders cultivate about 60 % of the total tea acreage and produce more than 75 % of the annual total production. In terms of productivity, the smallholder (1,995 kg/ha) (*Annual report of TSHDA*, 2019), subsector performs better than the corporate plantation sector (1,602 kg/ha). There are 1.5 million dependents in the smallholder sector. As a result, the tea industry's future in Sri Lanka will be largely determined by smallholders and their production practices.

Research Problem

Although tea smallholders at Doluwa sectorial division in Kandy district gain higher income by tea cultivation compared to other crops, they have to face more difficulties such as lack of essential inputs (fertilizer, chemicals, equipment, etc.), land degradation, low land, and labor productivity, high cost of production, inadequate outreach extension facilities, less effective conventional extension services and less knowledge and adoption of appropriate cultural practices of tea cultivation (Amarathunga; 2019, Perera;2014).

Several extension approaches were used in the tea smallholding sector in the past to help smallholders improve their living standards. But due to many restrictions, all of these approaches only partially succeeded in obtaining the required objectives. For example, when considering the farm and home visits approach, the field officers/ Tea Inspector (TI) to tea smallholders' ratio in the tea smallholdings sector is 1:2784, and the number of extension officers to tea smallholders needed for effective extension services is approximately 1: 1000 (*Annual report of TSHDA*, 2019). Amarathunga, (2019) explained that disputing the above facts, the number of officers must be increased in order to reduce the number of tea smallholders covered and improve the productivity of the extension service, but increasing the number of officers was difficult due to the institution's limits in terms of provisions and expenditure.

Under these scenarios, a pilot program of Farmer Field School (FFS) had been launched with the financial assistance of the Rehabilitation of Degraded Agricultural Land project of FAO (RDALP-FAO) by selecting tea smallholders in Grama Niladhari Divisions (GN) of Doluwa secretariat division of Kandy district in 2018. Tea Inspectors (TIs) and

Agriculture Research and production Assistants (*Kupanisa*) in respective ranges were trained for the Farmer Field School (FFS) concept and given the task of changing tea smallholders' attitudes and improving the adoption of appropriate cultural practices using the FFS approach.

Farmer field school approach

Since the late 1980s, support for agriculture has moved from top-down agricultural extension towards more participatory approaches that better suit smallholders. One such approach is the farmer field school (FFS), an adult education intervention that uses intensive discovery-based learning to promote skills. Accordingly, Bunyatta, *et al.,* (2006) found that Farm Field School (FFS) graduates had significantly higher levels of knowledge of the technologies presented compared to non-FFS tea smallholders in research on the FFS effectiveness for soil and crop management technologies in Kenya. In a study of the impact of FFS in the Philippines, Rola *et al*., (1998) discovered that in the FFS context, tea smallholders unravel their behavior with regard to the use of agrochemicals with the help of trained facilitators.

Although the FFS approach was introduced to the tea smallholders in Grama Niladhari Divisions (GN) of Doluwa secretariat division of Kandy district in 2018, no proper systematic assessment was undertaken in order to evaluate its effectiveness on rate of adoption of cultural practices towards the improving land productivity and profitability.

Objective(s)

General objective;

The general objective of this study is to evaluate the effectiveness of the Farmer Field School (FFS) extension approach in improving the adoption rate of cultural practices toward increasing tea smallholdings' land productivity and profitability of tea smallholding at the Divisional Secretarial area of Doluwa in Kandy District.

Specific objectives;

To evaluate the effectiveness of farmer field school (FFS) extension approach for improvement of knowledge on the recommended agricultural practices.

To evaluate the effectiveness of farmer field school (FFS) extension approach for the adaption of recommended agricultural practices.

To identify the effectiveness of FFS approach for improve land productivity of tea smallholdings.

To identify the effectiveness of FFS approach for improve the profitability of tea smallholdings.

To propose strategies for further improvement of effective use of FFS.

MATERIALS AND METHODS

The conceptual framework

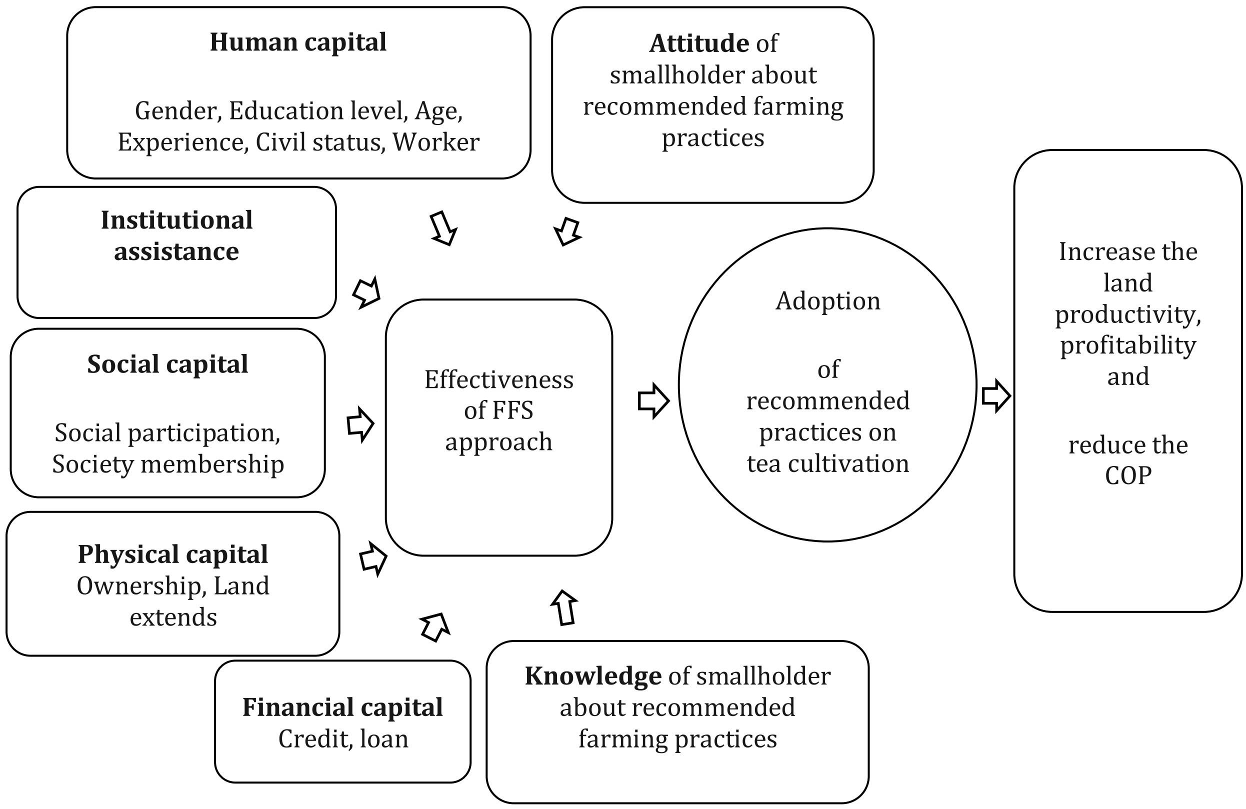

Figure 1: Conceptual framework for the study

The conceptual framework was developed for the evaluation of the effectiveness of the Farm Field School Approach which could attribute to the improvement of the adoption rate of cultural practices toward increasing tea smallholdings' land productivity and profitability. (Fig. 1).

Sampling method and location of study

A cross-sectional survey was performed and followed a stratified purposive sampling technique to select 50 farmers participating in FFS conducted in four Grama Niladhari (GN) Divisions (Lagumdeniya, Pabadeniya, Wariyagala, and Panvilathanna) and another 50 farmers who were not participating in FFS (NFFS) extension training approaches as a control group (NFFS), in the Grama Niladhari Division (Nawa Gurukale, Kahawaththa, Wawathanna, and Gonatuwela) of Doluwa Divisional Secretariat range in Kandy district.

Data collection

A Pretested structured questionnaire was validated by conducting a pilot survey and applying a reliability test, forces group discussion, and field observation were undertaken to collect primary data from tea smallholders of the FFS group and NFFS groups. The data on socio-economic status, knowledge, attitude, adoption level collected, Yield and cost of production from both groups, and data on further improvement and evaluation criteria, collected only FFS smallholders. To identify the effectiveness of FFS by comparing the information collected from FFS and NFFS groups.

Data analysis

Data gathered from the questionnaire were verified, cleaned, edited, coded, and entered into the computer software Excel and imported by STATA statistical package. A scoring system and 5-point Likert scales were developed to measure the variables and index. (Rathnayaka, Kithsiri and Gunathilaka; 2014).

Descriptive analysis, hypothesis testing, and Ordered Logistic Regression model was applied to measure variables and explain the relationship among the tested parameters. Consequently, an index was measured for each FFS and Non-FFS farmer separately by the Excel software. The following variables are used in the calculation of the index: the adoption of particular cultural practices by tea smallholders; farmers' knowledge and attitude of farming systems; the dynamics of the farmer group; farmers' social participation; and the evaluation criteria of the Famer Field School Extension Approach. (Amarathunga, *et al.*, 2021)

$$\text{Index of variabes} = \frac{\text{Marks achieved by farmer}}{\text{Total potential marks}} \times 100$$

Before the actual survey, the questionnaire was pre-tested with a small representative sample of 10 Tea small holders, and modifications were done.

Reliability analysis

The calculated alpha values of the questionnaire were higher than 0.700 with a significance of 5%. According to the result can conclude that the internal consistency was acceptable and the research tool was reliable and gave credible results.

Empirical Model

An empirical model was created to determine the effect of the following parameters the on adoption of recommended practices in tea cultivation.

$AL = \beta_0 + \beta_1GEN + \beta_2EDU + \beta_3EXP + \beta_4REL + \beta_5SOC + \beta_6KNW + \beta_7GRP + \beta_8LAN + \beta_9ATT + \beta_{10}SUS + \varepsilon i$

β_0 = Coefficient of constant, β_1 to β_{10} = Coefficient of variables, εi = Error

Table 1 presents the variables and their measurements, which were specified for the empirical model.

Table 1: Variable description of empirical model

Notation	Variables	Remarks
AL	Adoption level of recommended practices	Scores
GEN	Gender	If female = 1, Otherwise = 0
EDU	Education level of farmer	5-11 Grades = 0, O/L Pass = 1, A/L Pass = 2, Higher education = 3
EXP	Experience in tea cultivation	Years
KNW	Knowledge of recommended practice	Scores
LAN	Land productivity of tea land	Made tea per ha. per year
REL	Relevance of the FFS approach	5-Point Likert scale (1-5)
SOC	Social participation	5-Point Likert scale (1-5)
GRP	Group dynamic of the farmer group	5-Point Likert scale (1-5)
ATT	Attitude on recommended practices	5-Point Likert scale (1-5)
SUS	Sustainability of the FFS approach	5-Point Likert scale (1-5)

RESULTS AND DISCUSSION

The human capital characteristics of respondents

According to the sample's socioeconomic data (FFS and NFFS), 84% of the farmers were women who have participated to FFS. However, higher number of respondents (56%) in NFFS were male. About half (54%) of the farmers in the FFS group were between 37 -50 age range, but a higher portion (56%) of farmers in the NFFS group were in the above 51 age range. 24%, 56% and 20% of FFS framers in the sample respectively passed 5 -11 grades, O/L and A/L tests and 30%, 32% and 38% of farmers in the NFFS group respectively passed 5 -11 grades, O/L and A/L. In both the FFS and non-FFS groups, 85% of the farmers got married. All the farmers in both group (FFS and non-FFS) were cultivated their own lands.

Mean difference of Adoption level of recommended practices between FFS and NFFS groups

An important factor in determining the effectiveness of the FFS approach is comparing the adoption of recommended practices across FFS and non-FFS farmers. The study's findings (Table 2) reflect the mean value of adoption for recommended practices by FFS and NFFS smallholders.

Mwagi, *et al.*, (2003) found that FFS farmers adopted technologies for organic and inorganic fertilizer mixtures significantly more than non-FFS farmers did. Their findings were comparable to those in this study, where participants' average mean scores on the adoption level were much higher than non-participants'.

In contrast to NFFS smallholders, FFS smallholders had relatively higher mean adoption value, as shown in Table 2. The results also show that there were differences between the two groups that were statistically significant at the 5% level.

Table 2: Mean comparison of the index of adoption

Parameter	Group	N	Mean	Std. DE	Std. Error Mean	DF	P	t
Index of Adoption	FFS	50	2.16	0.5841442	0.0826105	98	0.0011	3.3620
	NFFS	50	1.78	0.5454828	0.0771429			

H_0 = the difference of the average adoption is equal to zero.
H_1 = the difference of the average adoption is not equal to zero.

For the FFS group and non-FFS group, the average rates of adoption are 2.16 and 1.78, respectively. The null hypothesis is rejected since the p value (0.0011) is less than the selected significance level $\alpha = 0.01$, thus the average adoption level for recommended tea cultivation practices differs substantially between the FFS group and NFFS group.

Adoption level frequency of recommended practices of FFS and NFFS groups

The adoption rate was medium for 74% of the FFS tea smallholders. In comparison to the low level of adoption, which was reported by 10% of small holdings, a high level of adoption was recorded by 26% of small holders (Table 3).

66 % of NFFS tea smallholders had a medium adoption rate. 6% of small holdings reported a high degree of adoption, while 28% of small holders reported a low level. (Table 4).

The findings show that more FFS smallholders than NFFS smallholders fall into the medium and high adoption groups.

Table 3: Results of frequency and percentage of adoption level for recommended practices of FFS respondents

Category	Adoption level	Frequency	Percentage (%)
Low	< 44	5	10
Medium	44– 52	32	74
High	>52	13	26

Table 4: Results of frequency and percentage of adoption level for recommended practices of NFFS respondents

Category	Adoption level	Frequency	Percentage (%)
Low	< 44	14	28
Medium	44 – 52	33	66
High	>52	3	6

Mean comparison of yield between FFS and NFFS groups

The evaluation of the FFS approach's effectiveness also considers the yield comparison between smallholders who participate and those who don't. Table 5. of the study's findings provides the yields for FFS and NFFS smallholders during the previous year (2021). According that FFS smallholders had a considerably greater tea yield (MT ha^{-1} yr^{-1}) than NFFS smallholders.

These findings are consistent with previous research showing the beneficial impact of FFS on production (Amarathunga *et al.*, 2021) For instance, the Peruvian study by Godtland *et al.,* (2004) found that the adoption of FFS increased farmers' knowledge of IPM methods and that this was significantly connected with productivity in the tea industry.

Table 5: Mean comparison of yield

Parameter	Group	N	Mean	Std. DE	Std. Error Mean	DF	P	T
Yield	FFS	50	926.18	315.5337	44.6232	98	0.0492	1.9916
	NFFS	50	823.74	180.8865	25.58121			

H_0 = the difference of the average yield is equal to zero
H_2 = the difference of the average yield is not equal to zero

For the FFS group and NFFS group, the average yields are (926.18 MT ha^{-1} yr^{-1}) and (823.74 MT ha^{-1} yr^{-1}), respectively. The null hypothesis is rejected since the p-value (0.0492) is below the chosen significance level of 0.05, indicating that there is a significant difference between the average yield of tea smallholders' land in the both groups.

Mean comparison of cost of production between FFS and NFFS groups

According to Table 6. FFS smallholders have a lower relative cost of production than non-FFS smallholders. The results further demonstrate that there were statistically significant differences between the two groups. By implementing proper field practices and adopting the new technical practices recommended by the FFS approach, FFS farmers have been able to lower the cost of production.

These findings are consistent with several previous studies that showed a reduction in production costs and an increase in profit when FFS recommended procedures are followed. (Rola (1998), Pincus (1999).

Table 6: Mean comparison on cost of production

Parameter	Group	N	Mean	Std. DE	Std. Error Mean	DF	P	T
Cost of production	FFS	50	165648.8	89529.44	12661.37	98	0.0001	-3.9769
	NFFS	50	221357.6	42377.09	5993.026			

H_0 = the difference in the average cost of production is equal to zero.
H_3 = the difference in the average cost of production is not equal to zero.

For the FFS group and NFFS group, the average cost of production is (Rs. 165648.8) and (Rs. 221357.6), respectively. The null hypothesis is rejected since the p-value (0.0001) is less than the predetermined significance level $\alpha = 0.01$, and it can thus be concluded that the average cost of producing tea is significantly different between the FFS group and the NFFS group.

The ordered logistic regression model analysis

An ordered logistic regression model was used in this study to analyze the influence of the chosen factors on FFS farmers' adoption of recommended practices for the production of tea because the dependent variable (level of adoption of recommended practices by FFS farmers) has several categories in order (high, medium, and low) (Table 7) (Amarathunga *et al.*, 2021).

Table 7: Results of the ordered logistic regression

Adoption level	Coef.	Std. Error	Z	P>[Z]
Gender	0.6193369	1.698114	0.36	0.715
Education level	2.240117	1.034522	2.17 **	0.030
Experience	0.2371756	0.1222906	1.94 *	0.052
Relevance index	0.026712	0.1150454	0.23	0.817
Social participation index	0.0868032	0.0603669	1.44	0.151
Knowledge	0.1080337	0.0422087	2.56 ***	0.010
Group dynamic index	0.3751019	0.1656411	2.27 **	0.023
Land productivity	0.0030917	0.0015439	2.00 **	0.045
Attitude	0.2968349	0.1712723	1.74 *	0.083
Sustainability	0.4055843	0.276183	1.47	0.141
/cut1	101.428	36.25091		
/cut2	110.792	38.45428		

*, **, *** significant at 10%, 5% and 1% significance levels respectively

According to the model summary, Prob > Chi^2 value is 0. 0000, which is less than 0.05 significance level indicating that the regression model as a whole fit significantly at 95% confidence level. The estimated model has a pseudo R square 0.5994. Accordingly, R square expresses that 59.94 % proportion of the variance in adoption level of recommended tea cultivation practices is explained by ten independent variables in the model. Among ten independent variables estimated six coefficients are significant.

Education level of tea small holders*;*

Farmers with education may quickly understand innovations (Feaster, 1968). The results show that, a unit increases in education level the change in probability is decreased by 5.88% at a low adoption level, 12.16% medium adoption level and a unit increases in education level the change in probability is increased by 18.04% at high adoption level. According to test results can conclude farmers with high educational levels are more likely to accept new technologies acquired through the novel extension approach of FFS.

Predicted Probabilities –Margins

Regarding Table 8, the marginal effect on farmers' level of education, level of knowledge, experience, attitude, FFS group dynamic, and land productivity can be shown as follows:

Table 8: Average Marginal Effect Results for low, medium and high adoption Level

Independent Variable	Average Marginal Effect ("1" low adoption level)		Average Marginal Effect ("2" medium adoption level)		Average Marginal Effect ("3" high adoption level)	
	dy/dx	**p value**	**dy/dx**	**p value**	**dy/dx**	**p value**
Gender	-.0174	0.730	-.0309	0.689	.0483	0.704
Education level	-.0588**	0.041	-.1216*	0.063	.1804**	0.023
Experience	-.0062*	0.082	-.0128**	0.047	.0191**	0.025
Relevance index	-.0007	0.819	-.0014	0.813	.0021	0.815
Social participation index	-.0022	0.155	-.0047	0.192	.0069	0.149
Knowledge	-.0028**	0.039	-.0058***	0.005	.0087***	0.000
Group dynamic index	-.0098***	0.005	-.0203*	0.097	.0302**	0.029
Land productivity	-.0000*	0.071	-.0001*	0.059	.0002**	0.029
Attitude	-.0077*	0.089	-.0161	0.129	.0239*	0.081
Sustainability	-.0106	0.121	-.0220	0.186	.0326	0.133

*, **, *** significant at 10%, 5% and 1% significance levels respectively

Experience of tea small holders

The results indicate that a unit increases in farming experience of tea small holders the change in probability is decreased by 0.62% at a low adoption level, 1.28% medium adoption level and a unit increases in education level the change in probability is increased by 1.91% at high adoption level. There was tendency to adopt suggested techniques when smallholders farming experience increased. It could be because smallholders have become more aware of tea farming practices over time.

Knowledge of tea small holders

The marginal values for knowledge of tea small holders for low adoption, medium adoption, and high adoption levels are - 0.28%, -0.58%, and 0.87%, respectively. When tea smallholders have a high level of knowledge regarding tea cultivation techniques, they focus more on the new technology they acquire via the FFS approach. These findings are consistent with previous studies by Hashemi, *et al.*, (2008), that showed knowledge has a significant effect on the adoption of new technologies like IPM.

Attitude of tea small holders

The results indicate that a unit increases in farming attitude of tea small holders the change in probability is decreased by 0.77% at a low adoption level and increased by 2.39% at high adoption level. Smallholders that have a positive attitude are likely to incorporate new technologies gained through the FFS approach into their cultural practices. This result is consistent with earlier research. According to investigations by Erbaugh, *et al.*, (2010) the effect of FFS courses on farmers' attitudes about the adoption of agricultural practices.

Productivity of tea land

The marginal values for productivity of tea land among the FFS of farmer for low adoption, medium adoption, and high adoption levels are - 0.00%, -0.01%, and 0.02%, respectively. The farmers with high land productivity are open to incorporating farming techniques with new technology they have access through the FFS approach. (Godtland *et al.,* 2004; and Amarathunga *et al.*, 2021).

FFS group dynamics index

The marginal values for group dynamics among the FFS of farmer for low adoption, medium adoption, and high adoption levels are - 0.98%, -2.03%, and 3.02%, respectively. The results of the study show that the FFS approach is facilitating group dynamics among the FFS of farmer groups through participatory and interactive learning, sharing of inputs and information, group decision-making, problem-solving, and discovery-based learning, among other things, and has a significant impact on the adoption of farming practices related to tea cultivation. These findings are consistent with previous studies by (Chandra, *et al*., 2017) which described the factors affecting group dynamics.

Strategies for further improvement of FFS approach

Some strategies have been suggested for further improvement of the FFS approach. According to the majority of the FFS smallholders, the number of group members for an FFS program, the number of sessions, and the number of days per week are better to be increased, and the time period allocated for a single session is better to be reduced.

RECOMMENDATION AND CONCLUSION/S

The findings confirm that the FFS approach considerably affects the productivity improvement of the tea lands and successfully lowers the cost of production associated with field practices of FFS participants' group compared to the NFFS group. This is because it allows for the acquisition and efficient application of newer production technologies, knowledge, and associated agronomic practices.

Also, the findings reveal that the education level of smallholders, experience in farming practices, knowledge level of smallholders, the productivity of tea land, smallholders' attitude about the novel farming technologies, social participation of smallholders, and group dynamic activities of the FFS farmers in attending the FFS extension program make a significant influence on the changing attitudes towards the adoption of recommended practices and novel agricultural technologies related to tea cultivation.

Based on the study's findings, it is clear that the FFS approach is an effective platform for creating agricultural innovations and distributing them among tea smallholders. Also, it ensures that tea smallholder is willing to long-term engagement with FFS extension activities towards adopting recommended cultural practices related to tea cultivation for improving their land productivity and profitability**.**

Hence the policy makers should be taken in to consideration that this approach could be effectively introduced for the improvement of productivity and profitability of tea smallholders in Sri Lanka.

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ECONOMIC FEASIBILITY OF INTEGRATING *JAMNAPARI* GOAT INTO UNDERUTILIZED PASTURE LANDS UNDER COCONUT CULTIVATIONS: A CASE STUDY OF COCONUT RESEARCH INSTITUTE, SRI LANKA

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ABSTRACT

The coconut industry plays a vital role in the economy of Sri Lanka. Approximately 443,528 ha of land is cultivated with coconuts in Sri Lanka, and the estate sector itself contributes 40 % of the national production. This study was conducted to evaluate the economic feasibility of integrating Jamnapari goats into underutilized pasture lands under coconut cultivations managed by the Coconut Research Institute of Sri Lanka. Naturally grown and improved pasture samples were collected from two coconut estates in Bandirippuwa and Makandura, Sri Lanka. Quadrat cut samples were taken randomly and analyzed for dry matter availability (kg/ha), crude protein (CP), and crude fibre (CF). An economic feasibility analysis was carried out based on average dry matter yields and respective carrying capacities of pastures and related production and economics data. The mean dry matter yield of natural and improved pastures ranged 2141±193 kg/ha to 3314±212 kg/ha and 4231±407 kg/ha to 9152±531 kg/ha, respectively. Accordingly, CP and CF of natural and improved pastures ranged 6.3±0.2 % to 18.5±0.2 % and 30.0±0.4 % to 33±0.3 %, respectively. Grass and legume percentages of natural and improved pastures varied from 1.9 % to 66.3 % and 7.0 % to 83.9 %. Estimated Jamnapari goat carrying capacities for natural and improved pastures were 8-11 heads/ha and 24-27 heads/ha, including does, kids, and a buck, respectively. The net present value (NPV) for the coconut monoculture system was around 0.45 million rupees, whereas, for integrated systems with natural and improved pastures, it was 1.4 and 4.7 million rupees, respectively at a 15 % discount rate for 10 years. This study concluded that the economic feasibility and profitability were higher when goats were integrated with improved pasture and natural pasture, respectively, compared to monoculture.

Keywords: Coconut, Economic feasibility, Goat, Integration, Pastures

INTRODUCTION

Coconut *(Cocos nucifera L.)* cultivated land extends in Sri Lanka is approximately 443,528, and the coconut is the most widely cultivated plantation crop of the island nation (Central Bank of Sri Lanka, 2020). Therefore, this industry is an important source of foreign exchange and employment generation for Sri Lanka. Further, Coconut is an essential component of Sri Lankan cuisine, nutrition, and rural livelihood (Pathiraja *et al.,* 2015). Due to the morphological characteristics of a coconut tree, the land use efficiency can be low when coconut is grown as a monoculture. Due to the wider spacing allowed between coconut palms for root growth and canopy distribution, only about 25 % of the land area is utilized under coconut in monoculture (Peiris *et al.,* 2010). Growing coconut along with various other crops is common in most coconut-growing regions to maximize land use efficiency (Raveendra *et al.,* 2021). Meanwhile, livestock integration is becoming popular among coconut cultivators as it can benefit resource exchange, especially in areas where arable land is limited for intercropping. Rising costs of inorganic fertilizer and weeding have increased the cost of production of coconut and the highest proportion of expenditure for manuring and weeding (Senarathne & Sangakkara, 2009). To continue the high soil fertility of coconut lands, the organic matter content and other factors need to be improved (Atapattu *et al.,* 2017). Integration of livestock is beneficial to the productivity of coconut lands while reducing the cost of production, especially for manuring and weeding, and increasing nutrient recycling and soil fertility (Ferdinandez, 1978). Naturally-grown pastures under coconut contain indigenous grasses, herbs, and legumes (Somasiri & Premarathne, 2017) and can be a good pasture source for integrated animals.

Cattle, buffalo, goats, and sheep are predominantly used in the integration of livestock production systems under coconut plantations in the world (Devendra, 2007). At present small ruminant production systems are becoming popular considering the need for less management, adaptation to adverse conditions, and higher productivity per unit area (Kosgey *et al.,* 2006). Therefore, introducing smaller ruminants such as goats and sheep into coconut lands can be a potential for a further increment of productivity of coconut lands (Seresinhe *et al.,* 2012). Integrating smaller ruminants into the natural vegetation available in underutilized pastures in coconut lands will bring additional food sources and income to the country using the existing resources. If improved pasture, fodder, and creeping legumes are cultivated under the coconut, the carrying capacity of animals can be multiplied depending on the inputs (Ferdinandez, 1978). However, there can be many economic factors affecting the integration process. Therefore, before this activity, assessing the economic feasibility of the integration to determine whether the process is economically viable to proceed is essential (Dunning & Robson, 1987). If this activity is feasible enough, other coconut lands with underutilized pastures can also be considered for small ruminant integration. Therefore, this study aimed to assess the economic feasibility of goat integration into the underutilized pastures in coconut lands and to identify the level of goat carrying capacity under natural and improved pasture categories in coconut lands.

MATERIALS AND METHODS

Location and sample collection

The experiment was carried out in the Agronomy Division, Coconut Research Institute, Lunuwila (7 20’ 37N, 79 51’ 42E) which is located in the intermediate zone of Sri Lanka. Pasture samples were collected from natural (uncultivated) and improved (cultivated) pastures from Bandirippuwa and Makandura estates, respectively. Coconut lands in the Bandirippuwa estate contained uncultivated or natural pastures for a long period, and at Makandura estate contained separately cultivated fields of improved pasture varieties of *Brachiaria brizantha*, *Brachiaria ruziziensis*, and *Brachiaria milliformis*. Natural pastures were further categorized according to identified fields with high grass composition (high grass), high legume composition (high legume), low grass composition (low grass), and grass-legume balanced composition (grass-legume mixed). Quadrat cut samples (n=9) were collected randomly from each identified field under coconut to estimate dry matter availability. A separate set of grab samples (n=9) were collected randomly to determine the botanical composition of each pasture type.

Botanical composition of pasture

Each grab sample was mixed, and approximately 40 g was weighed and sorted into grass, legumes, weeds, and dead matter, and botanical composition was calculated on a dry weight basis. The following equation was used to calculate the percentage of grass, legumes, weeds, and dead matter.

$$BC = (\square\square/FW) \times 100\ \%$$

Where,

BC = Botanical composition
DW= Dry sample weight (Grass, Legumes, Weeds, Dead Matter)
FW= Fresh sample weight

Determination of dry matter yield

Each quadrat cut sample was dried at 60 °C to a constant weight. The following equation was used to calculate the percentage of field dry matter yield (kg/ha).

$$DM\ (kg/ha) = \frac{DW\ (kg)}{0.0929\ (m^2)} \times 10000$$

Where,

DM= Dry Matter yield (kg/ha)

DW= Dry quadrat cut sample weight (g)

Area of the quadrant= 0.0929 (m^2)

Proximate composition of pasture samples

The dried sample used for dry matter content estimation was ground and sieved and used to determine laboratory dry matter content, crude protein, crude fiber, and ash percentages. Crude protein content was determined using the standard Kjeldahl method. Crude fiber content was determined using fiber determining apparatus, and ash content were determined using a muffle furnace at 600^0c for 4 hours.

Estimation of Carrying capacity of Jamnapari goats

The mean dry matter yields were used to determine dry matter availability for the integration of goats. The area reserved for manure circles per hectare was reduced from the calculated dry matter yield (1607.4 m^2). As all the dry matter would not be utilized an 80 % and 90 % utilization, respectively for natural and improved pastures were considered. The remaining dry matter availability was divided from the average dry matter.

The average dry matter intake of goats (3 % of body weight) was used to estimate the carrying capacity of goats. The average weight of a doe through the productive period, the average weight of a kid before selling, and the average weight of a stud buck through the productive life were calculated to determine the average dry matter intake of the herd with does, kids, and a buck.

$$\text{Carrying Capacity} = \frac{(\text{Available Dry Matter(kg/ha)} \times \text{Utilization \%})}{\text{Dry Matter intake of the herd (1 doe } + 2.25 \text{ kids} + 1 \text{ buck) per year}}$$

The first batch of does and bucks were assumed to be bought at the breeding age of 11 months and then replaced with the kids born when they reach sexual maturity and serviced at 11 months.

Cost-benefit analysis

According to the data collected and calculations made a cost-benefit analysis was performed, and net present value (NPV) and benefit-cost ratio (BCR) were calculated to assess the costs, benefits, and net cash flow of coconut monoculture, goat farming, and integration.

$$\text{NPV} = \sum_{t=1}^{n} \frac{\text{Bt}}{(1+r)^{\text{t}}} - \sum_{t=1}^{n} \frac{\text{Ct}}{(1+r)^{\text{t}}}$$

$$\text{BCR} = \frac{\sum_{t=1}^{n} Bt/\,(1+r)^{t}}{\sum_{t=1}^{n} Ct/(1+r)^{t}}$$

Where,

Bt = value of benefits in the t^{th} year
Ct = value of costs in the t^{th} year
t = Time period/year
r = Discount rate
In calculating NPV, a discount rate of 15 % was used

RESULTS AND DISCUSSION

Botanical composition of improved pastures

Three improved *Brachiaria* species (*Brachiaria brizantha, Brachiaria ruziziensis* and *Brachiaria milliformis*) were selected under improved pasture categories. When comparing the above three species, *Brachiaria brizantha* showed higher grass and dead matter percentage than *Brachiaria ruziziensis* and *Brachiaria milliformis.* The highest weeds and legume percentage showed *Brachiaria milliformis* when compared with *Brachiaria brizantha* and *Brachiaria ruziziensis* (Fig. 1).

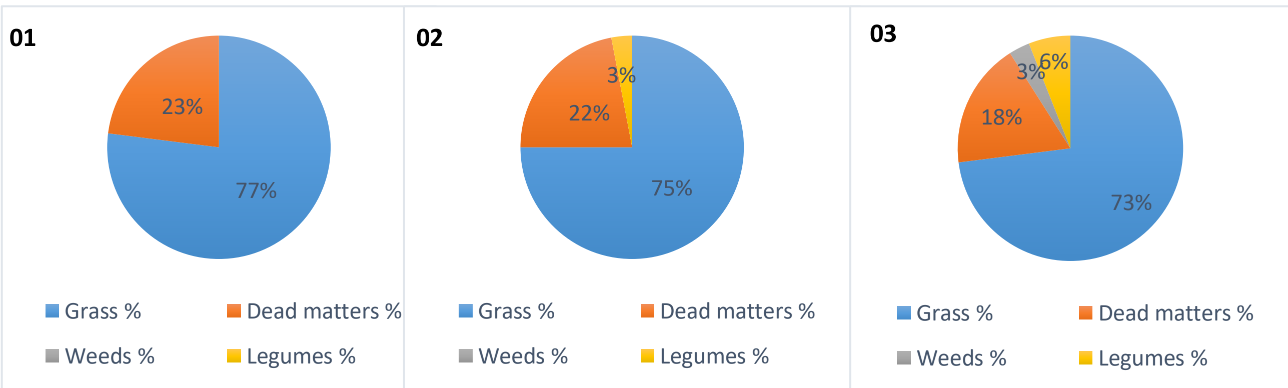

Figure 1: Botanical composition of improved pastures; (01) *Brachiaria brizantha,* (02) *Brachiaria ruziziensis, and* (03) *Brachiaria milliformis*

Botanical composition of natural pastures

The high grass pastures showed the highest grass and dead matter percentage in the natural pasture category (Fig. 2). The low grass category showed the highest weed percentage under the natural pasture category. The high legume category showed the highest legume percentage of than other three categories. Legume percentage was higher in natural pasture categories compared to improved pasture categories. The prominent legume species was *Pueraria phaseoloides* in all the pasture categories, which were included as productive and persistent forage legumes on coconut lands pastures as a strategy to increase the supply of nitrogen to pastures (Andrade *et al.,* 2010).

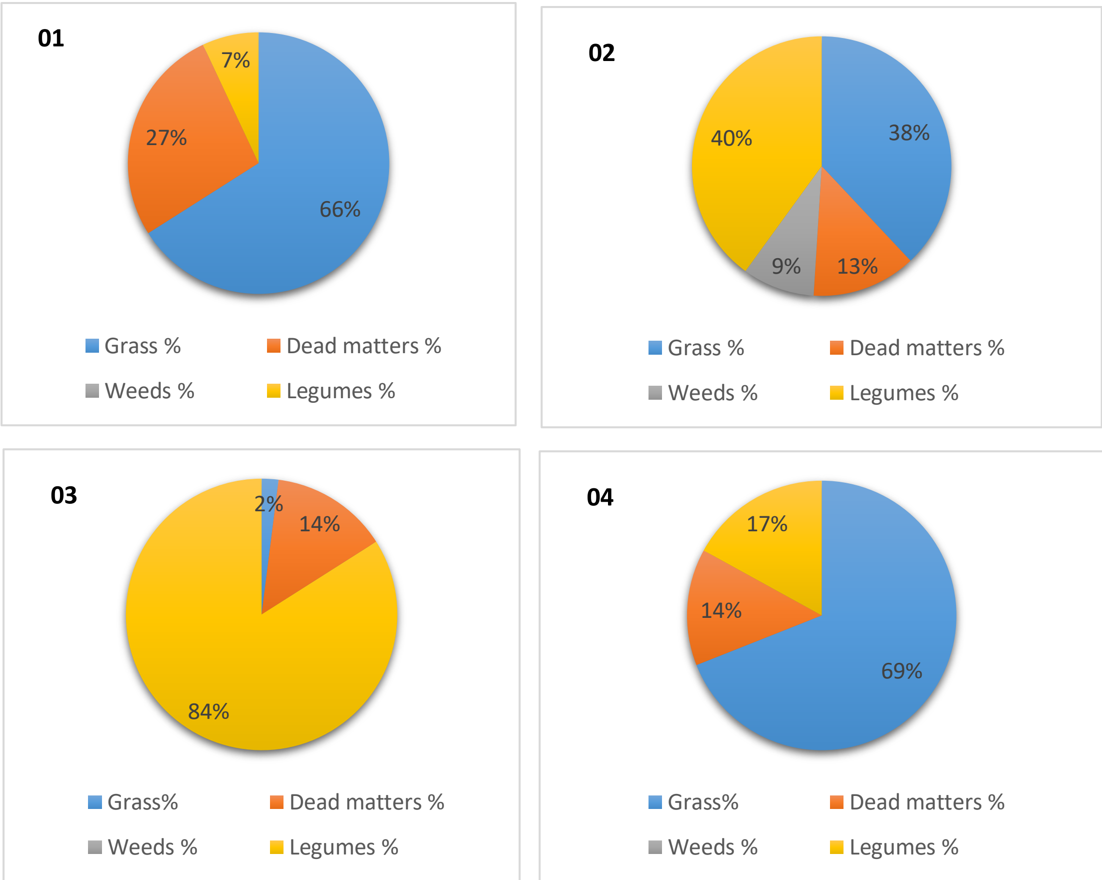

Figure 2: Botanical composition of natural pastures; (01) High grass category (02) Low grass category (03) High legume category, and (04) legume grass mix category of natural pasture

Dry matter yield (kg/ha) of pastures

Dry matter yield ranged between 2141 kg/ha and 9152 kg/ha between all pasture categories. The highest dry matter yield was observed in *B. brizantha,* and the lowest was in the grass-legume mixed category. When comparing all three improved categories there were significant differences among the three categories. When comparing all natural categories, only the high grass category showed a significant difference (Fig. 3). However, improved pasture categories indicated significantly different dry matter yields among natural categories except for high grass. According to Weerasinghe (2019), dry matter mass under farmlands was around 2500 kg/ha in the rainy season and 2000 kg/ha in the drought season, which is in the range of dry matter yields of natural pastures observed in the study. Dry matter yields of improved pasture varieties found in a previous study were 9000 kg/ha, 7700 kg/ha, and 7400 kg/ha in *B. brizantha*, *B. milliformis* and *B. ruziziensis* respectively (Guenni *et al.,* 2002). *B. brizantha* shows the highest dry matter yield, which agrees with the findings of the current study. Although in the current study, the yield of *B. milliformis* was lower than the above findings. It might be due to the comparatively higher weeds and legume percentages in *B. milliformis* fields (Fig. 3). According to Liyanage *et al.,* (1993) dry matter yield of *Pueraria phaseoloides* is 4.46 t/ha under coconut which is the prominent legume in the high legumes category of natural pastures and resulted in 3.31 t/ha in the current study.

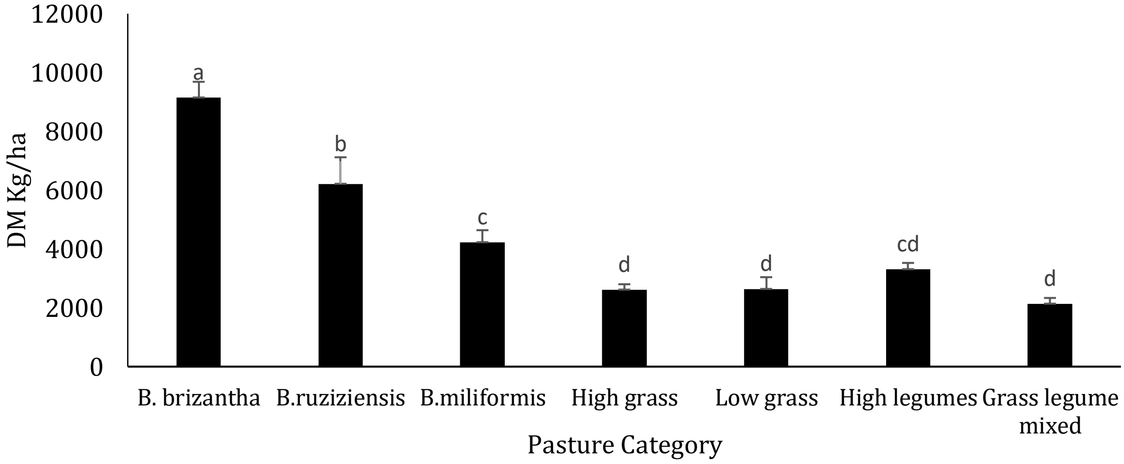

Figure 3: Dry matter yield of improved and natural pasture categories under coconut

Crude Protein content of pastures categories

The crude protein content of natural pastures varied from 9.9 % to 18.5 %, while it ranged from 6.3 % to 7.7 % in improved pastures. The crude protein content of natural pasture categories, low grass, high legumes, and grass-legume mixed categories were significantly higher (12.8 % to 18.5 %) than other improved pasture categories (6.3 % to 9.9 %). The highest crude protein percentage was observed in the high legume category of natural pasture (18.5 %) mainly due to the high proportion of legumes in the pasture (Fig. 4). All categories were compared with the lowest crude protein percentage in *B. brizantha* (6.3 %). It has also been found that the role of legumes in a mixed pasture is important for increasing nutritive value as well as digestibility and aids in fixing nitrogen and transferring them into grasses in the mixture (Ferdinandez, 1978).

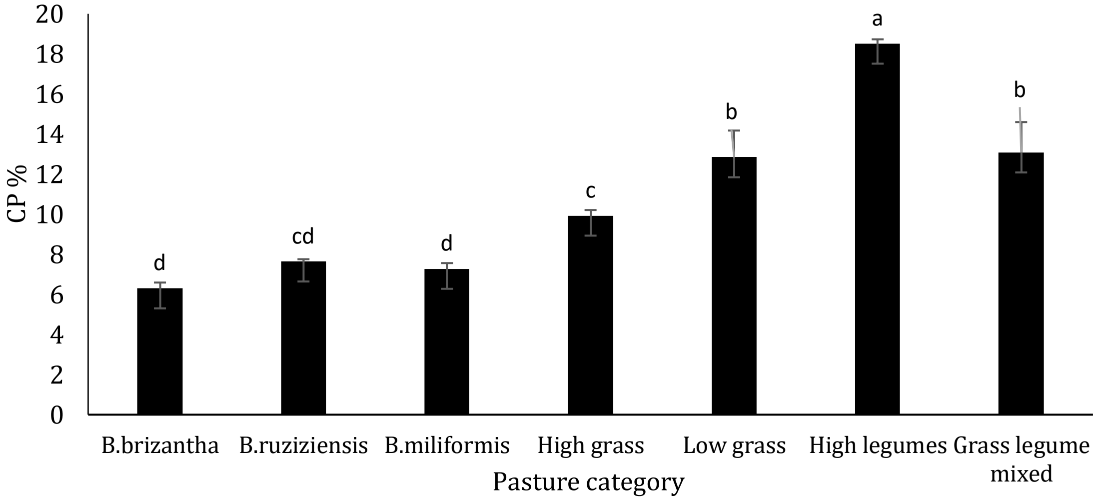

Figure 4: Crude protein content of improved and natural pastures under coconut cultivation

Crude fiber content of pastures

The crude fiber content of pastures shows less variation among pasture categories. There were less significant differences between improved and natural pastures. Crude fiber content varied from 30.1 % to 33 % among pastures (Fig. 5). The highest crude fiber percentage was in *B. miliformis* (33 %), and the lowest crude fiber content was in the grass-legume mixed category (30.1 %). Crude fiber content increases when pasture matures and affects the digestibility of pastures in animals (Ferdinandez, 1978). Therefore, the high crude fiber contents observed in this study could be due to the high maturity levels of pastures. It is likely, therefore, that the digestibility of pastures can be low in animals, however, organized rotational grazing can be used to alleviate this issue.

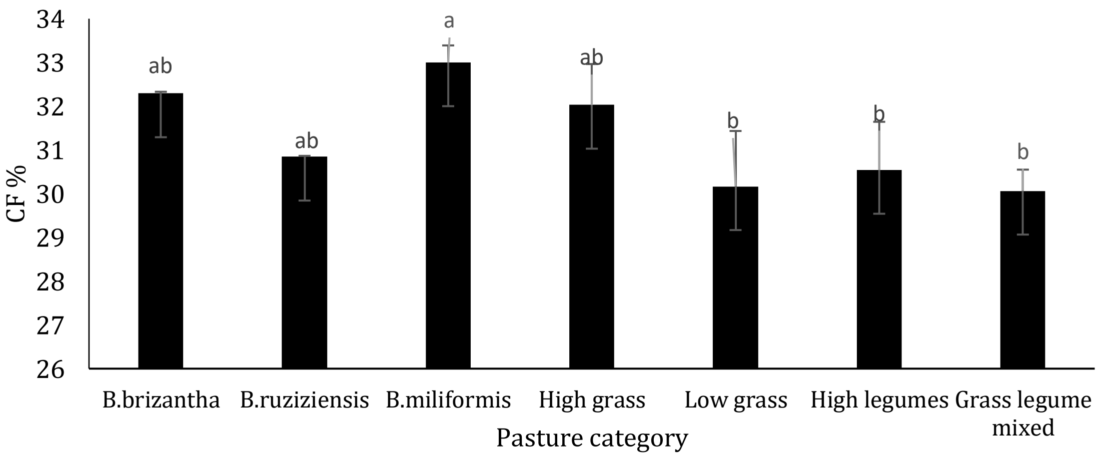

Figure 5: Crude fiber content of improved and natural pasture categories under coconut

Carrying capacity of goats under natural and improved pastures

Results from the carrying capacity calculation considering 80 % and 90 % utilization of available natural and improved pastures, respectively, it was found that with natural pasture under 1 ha land of coconut, 2 does, 5 kids and a stud buck would be able to integrate, and with improved pasture, it would be 8 does, 18 kids and a stud buck. Total herd sizes under natural and improved pastures were 9 goats and 27 goats per hectare, respectively. Table 01 shows the net cash flow for three main mono-farming systems in 10-year periods.

Table 1: Net cash flow for different farming systems for 10 years

System	Net cash flow (Rs)
Coconut monoculture (1 ha)	923,452.00
Goat mono farming with 2 does, 5 kids and 1 stud buck	1,312,720.00
Goat mono farming with 8 does, 18 kids and 1 stud buck	8,087,075.00

Costs and benefits of the coconut monoculture system

Compared to mono-cropping systems, intercropping and livestock integration provides farmers with more economic advantages. Farmers spend high-cost associated with maintaining a monoculture of coconut, from field planting to harvesting, which requires financial outlays. In order to reduce these costs intercropping and livestock integration with coconut can be shown as the best solution. These advantages lower the risk of natural disasters, improve pest and disease protection, increase land productivity per unit of land area and even incorporate into the farmer's life cycle. According to coconut statistics, table 02 shows costs and revenue in coconut monoculture after 10 years. (Ramrao *et al.,* 2005) reported that an integrated farming system is more beneficial than the arable farming system, which can augment income and bolster economic benefits.

Table 2: Costs and benefits of Coconut monoculture for 10 years

Process/Activity/Materials	Cost (Rs)	Benefits (Rs)
Fertilizer application costs- Cost for fertilizer, Transport cost, Removal of old mulch, Broadcasting, incorporation with soil, Replace mulch	2,983,035.00	
Harvesting related costs- Harvest by poles, collecting nuts, Transport to the main heap, Counting, Stockpiling, Loading to tractor	433,512.00	
Husk pit preparation- Excavation, cost for husks, arranging husks	534,500.00	
Weeding costs	533,000.00	
Nut selling		5,688,000.00

Costs and benefits of goat farming

Major costs involved in goat farming were the construction of a goat shed, purchasing breeding does and stud buck at the commencement, Concentrate and mineral feeding for kids, pregnant does, lactating does and bucks during service, deworming, other medicines and management practices, electricity, equipment costs and labor cost (Table 03). Table 04 showed the total revenue from the number of goats equal to the carrying capacity in natural pastures was Rs. 3,591,600.00, and that of improved pastures was Rs.12,756, 575.00

Table 3: Total costs involved in goat mono farming with respect to different carrying capacities calculated for natural and improved pasture for 10 years

Cost	Natural pastures (Rs)	Improved pastures (Rs)
Construction of goat shed	94,700.00	157,864.00
Purchasing of breeding does	102,000.00	408,000.00
Purchasing a breeding buck	21,600.00	21,600.00
Concentrate feeding	235,092.00	897,702.00
Mineral feeding	206,889.00	719,889.00
Deworming	8,149.00	26,545.00
Other medicines	10,000.00	50,000.00
Electricity	10,000.00	10,000.00
Equipment costs	15,400.00	15,400.00
Labor cost	1,575,000.00	2,362,500.00

Table 4: Total revenue involved in goat mono farming with respect to different carrying capacities calculated for natural and improved pasture for 10 years

Benefits	Natural pasture (Rs)	Improved pasture (Rs)
Sale of kids	799,217.00	3,449,698.00
Sale of old does leaving the herd	157,500.00	630,000.00
Sale of old bucks leaving the herd	100,800.00	100,800.00
Sale of manure	654,883.00	2,112,277.00
Sale of milk	1,879,200.00	6,463,800.00

Integration of goats with coconut and pasture

Integration of the number of goats equal to the respective carrying capacities for natural and improved pastures was considered. The changes in the integration process were assumed as the cost for weeding is reduced by 60 % by integration, and the manure produced is not sold but applied for coconut palms (Devendra, 2011). Ferdinandez (1973) showed that naturally occurring pasture under coconut had low yields, low quality, and a low response to added fertilizer. According to the results of the study, manure production is not complete enough for the fulfillment of the manure requirement of coconut palms in a hectare. The average number of trees that can be manured varied from an average of 20 to 95 palms per hectare for integration with natural and improved pastures, respectively. So, additional costs for inorganic fertilizer would be needed to fulfill the requirement. Therefore, for higher manure production, it would be ideal for increasing the herbage biomass by introducing and maintaining pasture to increase the carrying capacity of the lands. Table 05 shows the total cost total benefits, and net cash flow under natural and improved pasture categories.

Table 5: Costs, benefits, and net cash flows of integration for 10 years in a one-hectare land

	Integrated system with natural pasture	**Integrated system with improved pasture**
Total costs (Rs)	5,720,966.00	7,262,521.00
Total benefits (Rs)	8,624,717.00	16,332,298.00
Net cash flow (Rs)	2,903,751.00	9,069,777.00

The highest benefit and highest cost of production (COP) showed goats integrated with improved pasture categories, and the lowest benefits and lowest COP showed goats monoproduction systems with natural pastures (Fig. 6). The highest net cash flow showed in the goat integration with improved pasture compared to the other four systems.

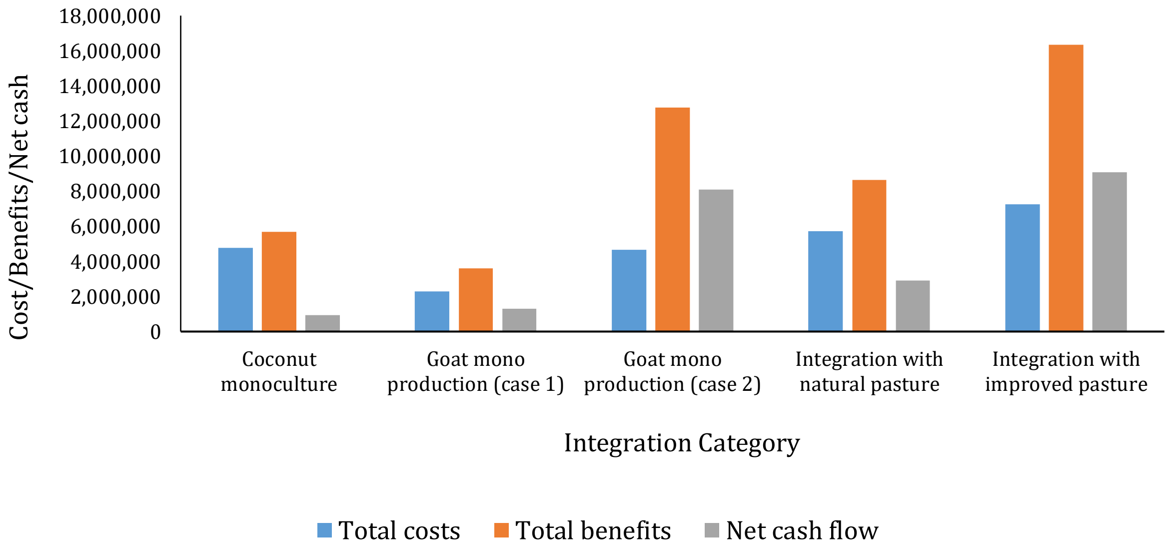

Figure 6: Total costs, benefits, and net cash flows for different systems for 10 years (Case 01 is goat mono production with a number of goats similar to the carrying capacity in natural pastures, and Case 02 is goat mono production with the number of goats similar to the carrying capacity in improved pastures)

The second highest net cash flow was from the Goat mono production (case 02), which is raring the number of goats without integration, equal to the carrying capacity of improved pasture under one hectare of coconut. It is higher than integrating the same number of goats under one-hectare land of coconut. The reason is that the benefits of the number of goats, in that case, are higher than the benefits of coconut cultivation as the number of sales of kids is higher, and milk production is higher. Also, as manure is sold, it gives additional income than cost saving for manuring coconut in integration. Goat mono production (case 1), which is raring the number of goats without integration that is equal to the carrying capacity of natural pasture under one hectare of coconut, gives the lowest net cash flow due to less number of goats reared.

Feasibility tools for assessing the profitability of integration

The results showed that Coconut-Improved pasture-goat integration has the highest NPV and BCR (Table 06) for 10 years at a 15 % discount rate while the lowest is for coconut monoculture. Therefore, it is feasible and profitable to practice the integration of goats under coconut rather than waste resources under coconut by monoculture system and increase the profitability and productivity of coconut lands. According to Seresinhe *et al.,* (2012), livestock integration substantially improved the income per unit cost from the total system. Also, that integrated system represents a key solution for enhancing livestock and coconut production and safeguarding the environment through prudent and efficient resource use.

Table 6: Variation of NPV and BCR between coconut monoculture (1ha) and integration of goats into coconut (1ha) at a 15 % discount rate (Rs)

Cropping system	BCR	NPV (Rs)
Coconut monoculture	1.16	441,349.00
Coconut goat integration (Natural pasture)	1.41	1,432,149.00
Coconut goat integration (Improved pasture)	2.04	4,689,838.00

RECOMMENDATIONS AND CONCLUSION/S

The results from the study have shown that the underutilized pastures under coconut lands can be used as potential resources for goat integration with sufficient dry matter yield (kg/ha) and other nutritive components such as crude protein and crude fiber. With resource availability, integrating goats into natural and improved pastures is more profitable than coconut monoculture. The net cash flow and net present values for coconut-natural pasture-goat integration have shown 3 % and 10 % increments than that of coconut monoculture, respectively. BCR is almost twice as high in coconut-improved pasture-goat integration than coconut monoculture. When comparing the coconut-natural pasture-goat integration system and coconut-improved pasture-goat integration, the net cash flow and NPV showed 3 % increments in coconut-improved pasture-goat integration. Therefore, it is profitable to practice integrating goats with pasture under coconut while integrating goats with improved pasture rather than natural pasture.

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EFFECT OF SOCIO-PERSONAL AND SOCIO-ECONOMIC ATTRIBUTES ON COLLECTIVE ACTION IN TEA SMALLHOLDING DEVELOPMENT SOCIETIES IN SRI LANKA

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ABSTRACT

Farmer organisations (FOs) are predominantly voluntary organisations and were formed to address some of the basic resource-related issues faced by smallholder farmers through a collective approach. Tea industry is one of the prime industries that bring much-needed foreign income to Sri Lanka, and smallholders are the key stakeholders in the industry. In order to effectively and efficiently provide the services of the tea smallholding Development Authority, the government of Sri Lanka established Tea Smallholding Development Societies (TSHDS) through a legislative act. However, in reviewing the sectoral indicators, a lack of engagement in the intended function of TSHDS can be identified. Several key factors can influence the collective action of FOs, and members' socio-personal and economic attributes (SPEAs) are one of them. However, FOs have less control over on SPEAs. This study attempted to examine the relationship between selected SPEAs of members and the collective action of the FOs. members and the collective action of the FOs. About 621 individuals of different TSHDS from six major tea smallholding districts were randomly selected, and their various SPEAs and levels of contributions were analysed using descriptive, chi-square and log-linear statistical tools. The study appraised the TSHDS members' SPEAs and revealed that they were at marginal scales in most cases. According to the results, members' SPEAs show mixed effects on different types of collective action endeavours. Although some SPEAs show influence on collective action endeavour related to social type, no such effect is seen concerning commercial-type activity. When significant associations exist, the strength of the association is not strong according to the coefficients. The outcome of the log-linear analysis also indicated that SPEAs do not strongly influence members' collective contributions. In conclusion, these attributes alone do not play a decisive role in inducing the members' collectivism; Instead, other factors may influence collective action.

Keywords: Association, Collective action, Socio-personal and socio-economic attributes, Tea smallholders, Tea Smallholding Development Societies,

INTRODUCTION

Farmer organisations (FOs) are considered Community-Based Organisations in the agriculture sector, particularly in the farming community. Low financial capital and inadequacy of other resources are common problems faced by smallholder farmers, and FOs were formed to resolve these issues through a collective approach. (Barham and Chitemi, 2009). FO is an entity that represents the farmers in a given geographical area and deals with the agriculture enterprise-related needs of the members (Esham, 2012). Therefore, FO remains essential to empower rural farmers, alleviate poverty, and uplift their living standards. However, the existence of the FOs is greatly challenged in the present neoliberal economic context (Datta, 2004). This situation appeared to be mainly related to the extent to which they are market-oriented (Chamala & Shingi, 1997). This scenario can be further understood in the light of modernisation theory, where market integration is a key element emphasised in the development process (Rostow, 1960).

As 73% of the total production comes from the tea smallholding sub-sector (TSHDA, 2020), tea cultivation in Sri Lanka is currently dominated by tea smallholders. The emergence of smallholders is noticeable in many tea-growing countries (CPDA, 2008; FAO,2012; World Tea News, 2018). It may be the best management unit that combines the other production factors in the relevant socio-economic context. Some studies have suggested managing the corporate sector tea lands under small-scale management units (Dishanka & Ikemoto, 2014; Shyamalie, 2014). Nevertheless, that does not mean that there are no problems in the tea smallholding sub-sector. Here one of the main issues is articulated. The development activities in the tea smallholding sub-sector are handled by TSHDA, which was established in 1977 under act no 35 of 1975. Tea Inspector (TI) is the grassroots level extension worker who associates with tea smallholders at the field level in a respective region (Obeysekara, 2009). However, due to a large number of farmers and also the fact that they were largely disorganised, it was difficult to provide their services effectively and efficiently. Furthermore, TSHDA experienced difficulties in implementing group extension approaches and participatory development activities. Under these circumstances and in view of the global development situation, the government formally established Tea Small Holding Development Societies (TSHDS) through legislative Acts No. 36 of 1991. However, reviewing sectorial indicators (productivity, production, replanting, technology adoption, average income of the tea smallholders), there is a shortfall in engaging in the expected task such as developing smallholdings, providing marketing facilities, promoting economic and welfare activities, and providing financial support by the TSHDS (TSHDA, 2008-2018; ILO, 2018). Does this imply that they are in a crisis? Some studies showed that the collective activism of TSHDSs was not satisfactory (Bandula *et al*., 2016; ILO, 2018; Mahindapala, 2020).

As mentioned above, the lack of a strategic approach to deal with challenges in a neoliberal economic context is one of the reasons for the declining performance of FOs as voluntary organisations (Borshtoem, 2013). According to the results of some studies, some other factors such as weak leadership, poor attitudes of leaders, cultural and religious ideological conflicts, political influences and structural problems of FOs have also led to the decline of FOs (Rajaratne, 2007; Esham *et al.,* 2007). Political influence and structural problems seem to go together (Mahindapala, 2020). Furthermore, Esham (2012) has observed that FOs, which have some obligation to the government because of the legislative acts that they were established, are more vulnerable to such situations. Dependency theories also explain how dependency status leads to poor efficiency (Vernengo, 2004; Deborah & Stephen, 2004). Furthermore, when FOs are dependent on the state, the inefficiency of the relevant government officials appointed to serve the FOs also contributes to the poor performance of the FOs (Gerragama *et al.,* 1999).

Collective action is an essential element for the effectiveness of a voluntary organisation. Collective action greatly influences the efficacy of FOs (Mahindapala, 2022). Collective action can be defined as a group of people performing together to achieve a common task (Gillson, 2004). Several factors can influence the collective action of a voluntary organisation -social relations within the organisation (Ostrom, 2000; Coleman, 1998), availability of incentives (Olson, 1965), level or type of sanctions (Gillson, 2004), perception of fellow members (Willer, 2009) and some socio-personal and economic attributes of members (Assante *et al.,* 2011). Unlike other factors mentioned above, the FOs have less control over these socio-personal and economic attributes (SPEA). Hence, they have the potential to have higher variability within a given FO. This was well evident in the appraisal carried out in four selected Farmer Producer's Organisations in Madya Pradesh in India (Singh *et al.,*2019). However, what is more important is to investigate whether the variability of these SPEAs accounts for the performance of the FOs. Bandula *et al.,* (2016) have identified that certain SPEAs have some bearing on the performance of TSHDS in Matara districts. However, apart from this attempt, there is no such attempts have been made to identify their influence on the collective action of the members.

In summary, the above discussion revealed that multiple factors could influence the efficacy and collective action of TSHDS. Analysing such factors would widen the existing knowledge. Using that knowledge, TSHDS can be strengthened in future endeavours, which would greatly impact the national economy. Several studies were conducted to investigate some of the above multiple factors (Mhindapala *et al.,* (2022); Mahindapala *et al.,* unpublished data (2023). Therefore, this study attempted to examine the relationship between selected SPEAs and collective activities.

MATERIALS AND METHODS

Eleven TSHDS from six major tea smallholding districts were selected purposively to draw the samples. These eleven TSHDS were chosen based on the previous research information of the main author. About 40 - 70 individuals who performed different levels of contributions with respect to the (i) participation in general meetings and (ii) supplying of crops to the TSHDS during the period 2017 – 2019 were randomly selected as research participants. Accordingly, data on SPEA, such as age, education level, size of tea land, whether the member is a full-time or part-time farmer, social status, gender, income level, and experience in tea society, were collected from about 621 members. Then % of crop supplies and % of meetings attended were collected as dependent variables. As far as possible, data was collected through records of tea associations (document survey), and data which are not available in respective TSHDS was collected through a telephone survey using a specific format (questionnaire). Then the data were categorised into five levels (Very low to very high) during the tabulation. Data analysis was performed using descriptive analysis, and to test the following hypothesis chi-square test was used. Hypothesis:

> Ho; There is no association between Socio personal and economic attributes and the contribution of the members (either by supplying green tea leaves or participating in meetings)
> H1; There is an association between Socio personal attributes and the members' contribution (either by supplying green tea leaves or participating in meetings).

RESULTS AND DISCUSSION

Appraisal of Socio personal and Socio-Economic Status (SPSES) of members

Age, Educational level, Gender, land size, Status, level of engagement in tea cultivation (Full-time/Part-time), Income level and experience in TSHDS were descriptively analysed and given in Tables 1 and 2

Table 1: SPSES of members of selected TSHDS

	The percentage of members comes under different categories of SPEAs				
Type of Category	**Age[1]**	**Education[2]**	**Land Size[3]**	**Experience[4]**	**Income[5]**
Low	14.4	33.6	31.0	32.6	48.0
Moderate	48.0	47.4	61.4	25.1	39.3
High	37.6	19	7.6	42.3	12.7

[1] Low - <40, Moderate – 41-60, High <61; (n=581)
[2] Low – Less than O/L, Moderate – O/L, High A/L and above (n=557)
[3] Low - < 1 ac, Moderate - more than 1-3 ac, High – more than 3 ac.(n=609)
[4] Low - < 8 years, Moderate 9-16 years, High – 17 years and above (n==621)
[5] Low - <30000 LKR Moderate 30000- 6000 0LKR, High - <600000

Table 2: Social Status, Gender and Level of Engagement in tea cultivation by TSHDS members

Status (n=394)		Gender (n=621)		Level of Engagement (n= 621)	
Category	**%**	**Category**	**%**	**Category**	**%**
Normal	94.2	Male	65.9	Fulltime	74.9
Elite	5.8	Female	34.1	Part-time	25.1

About 15% of members are under the age of 40, implying that young people are reluctant to stay in the Tea Society. Most members (85%) were over 40 years of age, with the largest majority of members (48%) in the 41-60 age group. Two third of the members passed at least the GCE (O/L) examination, of which 28% passed the GCE (A/L). The remaining one-third of the members of the selected TSHDS have varying levels of formal education up to grade eleven standards. The size of a tea land that the majority of the members had was 1 to 3 acres. About 42% of the members have worked as a member of the considered TSHDS for more than 17 years, and about 33% of the members joined the particular TSHDS within the last eight years. However, according to Table 1, it seems that the majority of recently joined members are not young members. More than 50% of the members have earned more than LKR 30,000.00 monthly income from the on-farm and off-farm activities, of which one-fourth have earned over 60,000.00 LKR. However, 48% of members declared that their income was less than LKR 30,000.00.

Further, about two third of the members are male, and all most 75% of the members (including those who have retired from permanent employment) were engaged in full-time tea cultivation. Out of the total respondent who responded, about 6% of the members were identified as rural elites.

Relationship between SPEAs and Collective action

The effect of SPEAs on collective activity was examined using two activities to represent the two streams. Attending the general meeting of the TSHDS was considered as a social type of activity, and the supply of crops by the members was taken as a market-related activity.

Impact of SPEAs on members' contribution related to social type activity

To find out the association between above two components, cross-tabulation was done, and test results are given in Table 3.

Table 3: Association between SPEAs and members and participation of members for the general meeting.

Socio personnel factor	Chi-square value	df.	p-value
Age of the member	9.07	4	0.059**
Social status	3.04	2	0.218
Size of the tea land owned	5.57	4	0.233
Educational level	9.87	4	0.043*
Experience in tea society	18.95	4	0.01*
Gender type of member (Male/Female)	4.92	2	0.085**
Level of engagement in tea cultivation (full-time or part-time tea growers)	8.01	2	0.018*
Income level (off-farm and on-farm)	6.03	4	0.197

*Significant at p<0.05 level; significant at p<0.1 level.

Interestingly, no significant association was detected between social status, size of the land, income level of the member, and contribution of the members. Income includes both on-farm and off-farm income, closely associated with class – the main social stratification criteria in Marxism. Status is another social stratification criterion identified by Max Webber, and perhaps in the traditional rural context, the influence of elites is the toughest.

However, the impact of modernisation would have wiped out such differences in rural settings. On the other hand, these three indicators, including the size of the tea land, apparently represent the privileged condition enjoyed by tea smallholders. Even though it was expected that less privileged people would contribute more and solve their problems, results showed no such evidence. Moreover, Mahindapala *et al.,* (2022) have shown that their organisation's culture lacks the deep level of discussion that leads to effective policy dialogue in TSHDS. Therefore, members might not have that kind of rational expectancy.

However, members' properties like educational level, experience and level of engagement in tea cultivation showed a significant association (at 95% CI) with respect to the contribution. Moreover, age and gender showed some association at 90% CI. According to the data (Table 4), among members with the least education, 44% show moderate or high contribution, 59% of moderately educated members show moderate or high contribution and 63% of members with relatively highly educated show moderate or high contribution. It shows that contribution improves with education. Further, Table 4 showed that about 49% of members with a short tenure (less than eight years) with TSHDS had high or moderate contributions. However, about 71% of members who have stayed with TSHDS for more than 16 years indicated a moderate or high participation level.

Table 4: Variability of the Members' contribution with education level and experience

SPEAs		**Level of contribution**		
Name	**Level**	**low (< 35%)**	**Moderate (35-65%) or High (>65%)**	**Total**
Education	Low	71 (56%)	56 (44%)	127
	Moderate	78 (41%)	116 (59%)	194
	High	17 (37%)	30 (63%)	47
Experience	Low	79 (51%)	76 (49%)	155
	Moderate	55 (55%)	45 (45%)	100
	High	38 (29%)	91 (71%)	129

A similar trend was observed with respect to age as age goes from low, moderate to high, and moderate and high contributions of members also improved by 42%, 56% and 60%, respectively (Table 5), which means that mature members make higher contributions. The results on age and experience further indicated that the TSHDS attraction to the youth is yet to improve.

Table 5: Relationship between Members' contributions with the age

		Level of contribution	
Age Level	**low (< 35%)**	**Moderate (35-65%) or High (>65%)**	**Total**
Low (20-40)	34 (58%)	24 (42%)	58
Moderate (41-60)	83 (44%)	106 (56%)	189
High (above 61)	56 (40%)	84 (60%)	140

As shown in Fig. 1, full-time farmers have given a relatively higher contribution to the TSHDS than part-time farmers. Tea cultivation is the main livelihood occupation of full-time farmers, and their determination, as well as their time availability, to contribute to TSHDS activities, is high than part-time members.

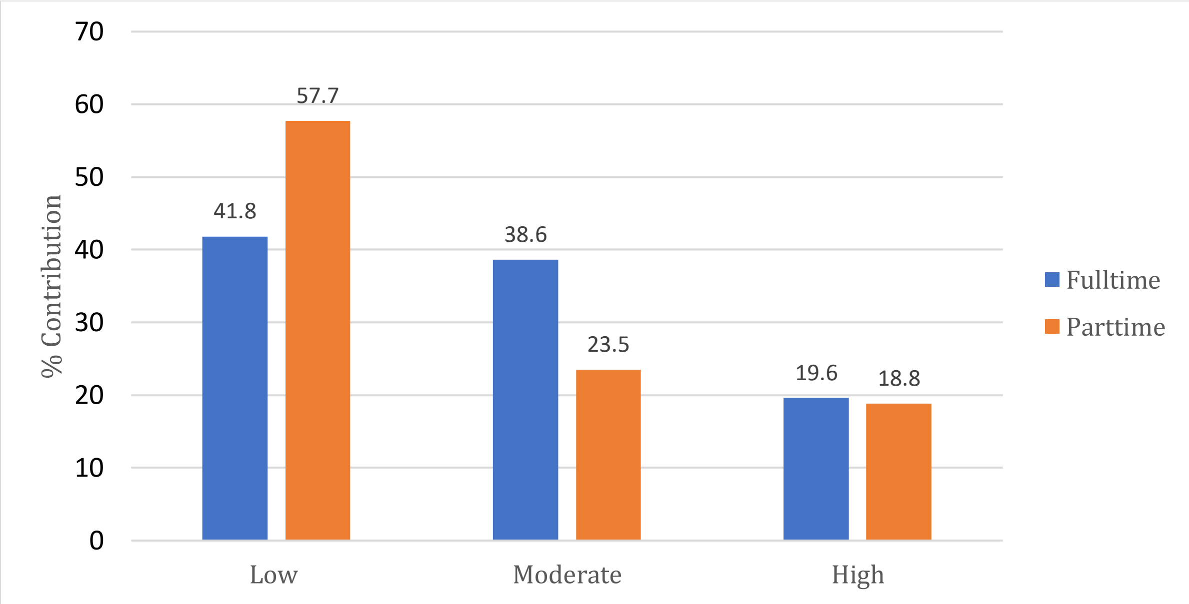

Figure 1: Contribution level of full-time and part-time tea growers.

Although several significant associations are noticed, the strength of the association is not that high according to the contingency coefficients shown in Table 6.

Table 6: Strength of the Associations

Name of SPEAs that became significance	Contingency coefficients	Phi
Age of the member	0.151	0.153
Educational level	0.167	0.164
Experience in tea society	0.217	0.222
Gender type of member (Male/Female)	0.112	0.111
Whether full-time or part-time tea growers	0.142	0.141

Therefore, it appears that considered socio-personal attributes alone do not play a decisive role in governing the TSHDS's collectivism. Instead, they will play a supporting role in improving other critical factors. Moreover, these socio-personal factors can foster individuals' prosocial behaviour and have the potential to interact with social capital dimensions such as relationships and common understanding.

Impact of SPEAs on members' contribution on market-related activities.

Similarly, the impact of the above factors on the dynamics of TSHDS was assessed. Accordingly, the variability of members' contribution in terms of crop supply to TSHDS was evaluated based on the above attributes. However, the analysis showed that no attribute other than the level of engagement in tea cultivation (chi-square 4.82 p= 0.09) significantly improved members' contribution (Table 7).

Table 7: Association between SPEAs and members' contribution to the supply of crops (as a market-related CA).

Socio personnel factor	Chi-square value	df.	p-value	Contingency coefficient
Age of the member	4.107	4	0.392	
Social status	2.73	2	0.255	
Size of the tea land owned	6.474	4	0.166	
Educational level	0.983	4	0.912	
Experience in tea society	5.688	4	0.224	
Gender type of member (Male/Female)	1.957	2	0.376	
Level of engagement in tea cultivation (full-time or part-time tea growers)	4.181	2	*0.09	1.33
Income level (off-farm and on-farm)	5.978	4	0.201	

* Significant at 0.1 level

An explanation that can be given for this is that collective action related to market or business-oriented activities is largely governed by individuals' desires to achieve benefits. Rational people are motivated to achieve benefits. They contribute when they get benefits. Otherwise, they do not contribute. Hence the effects of all other factors for collective action are suppressed by individuals' desires. Indeed, it is a major emphasis of Olson's (1965) theory. The degree of benefit from a process may be the main consideration that rational people take as an incentive. Hence, it appears that the SPEAs of the members have the least effect on the collective action related to business-related activities, which appears to be determined by the incentives associated with such events.

According to the above results, members' socio-personal and economic attributes show mixed effects on different types of collective action endeavours. Although some SPEAs show some influence on collective action endeavours related to social type, no such influence is seen with respect to commercial-type activities.

Furthermore, an attempt was made to fit a log-linear model to ascertain socio-personal factors' dynamics further. Out of the eight attributes, two were dropped at the initial stage as they were non-significant (in the chi-square test), and six attributes, along with collective actions (participation in the general meeting), were considered. The variables were considered to fit the following log-linear model.

$M_{x1\text{-}x7} = X_1+X_2+X_3+X_4+X_5+ X_6 + X_7 \ (X_1{*}X_2) + \ldots\ldots\ldots.(X_6\ X_7)$+ All 3 ways + All 4 ways +All 5 ways +All 6 ways All 7 ways

Where X_1 Participation level for a general meeting (Social type CA proxy)
X_2 = Age category of the members
X_3= Educational level of the members

X_4 = experience in tea society
X_5 = Gender type of member
X_6 = level of engagement in tea cultivation
X_7 = Monthly Income level

Using the loglinear analysis, the following hypothesis was tested:

Ho: No interaction among various SPEAs and particular social type CA proxy
Hi: At least there can be one interaction among the considered variables

This a step-wise procedure and only the hierarchical model is considered based on the degree of reduction of G^2 - Likelihood ratio (ΔG^2) and p-value approaching 0.05. The details of the step-wise procedure is given in Table 8.

The log-likelihood ratio (G^2) for step 1 (main effects) and all interactions was 114. 49 (p=0.005, df. =69) and 41.69 (p=0.727, df.=48), respectively. It indicated that the final model was in an intermediate stage. Out of twenty-one combinations, based on G^2 and p-value (Table 8), one interaction term was fitted (Age and Experience) to the model in the next stage, but none of the expected combinations (any attribute with a collective action). In the 3rd stage, out of three competing combinations, an interaction was chosen between education level and collective action (based on the p-value and ΔG^2 value), and the model was saturated. Thereafter, none of the combinations could be considered further (Table 8).

Table 8: Fitting log-linear model between socio-personal attributes and collective action.

Combination	df	G^2	ΔG	p-value
Only main effect	69	114.49		0.0005
All two-way interaction	48	41.69	73	0.7277
(Age X Experience)	68	92.4	**22.09**	**0.026**
(Age X Experience) +(Fulltime X Income level)	67	82.23	10.17	0.0995
(Age X Experience) +(Education X Collective action)	67	85.96	**6.44**	**0.0592**
(Age X Experience) + (Age X Gender)	67	90.39	2.01	0.03

Final Model - (Age X Experience) + (Education X Collective action)

According to the above model, the most dominating interaction that existed with respect to the particular interest area is age and experience (Period stay in the TSHDS). The age also increases when time is spent in the TSHDS; thus, this interaction between the two variables is understandable. In addition to that, education and collective action interaction also become statistically significant, which again indicates that when the education level of the members improves, their contribution level also increases.

However, out of the eight SPEAs that have been considered, only one attribute fitted to the model.

This analysis revealed that members' collective contributions are not strongly influenced by socio-personal and economic attributes and confirmed the arguments buildup in earlier. Therefore, the Collective action would have been attributed to the other factors mentioned in the literature. Moreover, Mahindapala *et al.,* (2022) have shown that collective action has a strong relationship with the efficacy of TSHDS. Furthermore, according to the findings of parallel studies conducted by the author, it has been shown that independence, state of regional development, leadership and intrinsic qualities of leaders and linkages with other organisations have largely contributed to the effectiveness of TSHDS (Mahindapala *et al.,* 2023). Moreover, these studies showed that the incentives generated within the system and the social capital status of TSHDS contribute to collective action (Mahindapala *et al.,* 2023). Such results show how the effectiveness of state-centric FOs is jointly affected by attributes proposed by two very different theoretical strands, Olson (1965) and social capital (Ostrom, 2000). Studies of Farmer Producer Companies in India and Japanese Agricultural Cooperatives showed that members strongly respond to the benefits they receive from FOs (Trebbin, & Hassler, 2012; Esham, 2012). Furthermore, FOs affiliated with ineffective organisations will not produce positive results (Rosairo & Esham, 2022). On the other hand, social capital can be used to overcome the lack of financial capital in a voluntary organisation (Ostrom, 2000; Amarasinghe & Bavinck, 2007). The findings of the present study, combined with secondary and unpublished data, suggest that socio-personal attributes are of minimal importance in enhancing TSHDS, and other variables should be addressed.

RECOMMENDATIONS AND CONCLUSION/S

No significant association was detected between the collective action and members' social status, land size and income level. These attributes are closely linked with the privileged condition enjoyed by tea smallholder members in the tea society. Even though it was expected that less privileged people would contribute more with a view to solving their problems, results showed no such evidence. Therefore, it does not appear that members could have such a rational expectation. However, members' socio-personal and economic attributes like educational level, experience and extent of engagement in tea, age and gender are significantly associated with the level of participation in general meetings, which is considered a social type collective action endeavour, which means that their contribution can be improved by manipulating these attributes. Although significant associations exist, the strength of the association is not strong according to the coefficients. Therefore, these attributes alone do not play a decisive role in inducing the members' collectivism. However, they can play a supporting role in improving social capital dimensions.

Nonetheless, when considering a supply of crop – one of the market-related collective action endeavours, most of these socio-personal and economic attributes do not influence it except the level of engagement in tea cultivation. Further, log-linear analysis confirms that socio-personal and economic attributes do not strongly influence members' collective contributions. Instead, other factors may improve the collective action of TSHDS.

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CAUSES FOR RUBBER HARVESTERS' TURNOVER INTENTION IN MEDIUM SCALE RUBBER HOLDINGS IN KALUTARA DISTRICT

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ABSTRACT

High turnover rate among the Latex Harvesters (LHs) in the medium-scale rubber (Hevea brasiliensis) smallholder sector in Sri Lanka has been an alarming signal for rubber productivity in the country during the past few years as LHs are the key players to determine the rubber production process. The objective of this study was to investigate on two independent variables namely Job Satisfaction (JS) and Organizational Commitment (OC) that were thought to be associated with Turnover Intentions (TI) of the LHs, with an effort to fill the research gap. The data was collected employing a self-administered questionnaire survey, from 231 LHs in rubber growing areas in Kalutara District, in 2020, where the sample was selected using a stratified random sampling technique. The variables were measured with the use of validated items. The responses of the LHs for the items were captured on a Five-point Likert scale. Female LHs were predominant in the sample (78%) and the age of the LHs varied from 19 to 71 years. The majority of LHs (58 %) have achieved more than ten years of work experience as a latex harvester with an average of 11 years. The average number of working days per week was four days. The majority (58%) of LHs were paid daily whereas about 38% of them on monthly. The mean wage rate was SLR 17,728 per month which varied from SLR 10,750 - 27,500. Nearly half of the LHs (54%) had not participated in any rubber related training programme. The composite two-predictor conceptual model was validly and reliably capable of explaining 76% of the variance in the TI of the LHs. Hypotheses for direct effect were tested using regression analysis. The findings revealed that JS and OC of LHs had a negative effect on TI. And also, three strategies; Enhancing the social recognition by introduction of National Vocational Qualifications (NVQ), Introduction of continuous rewarding system (Monetary and non-monetary) and Human resource development programmes with motivational approach are suggested to reducing the rate of turnover intention of latex harvesters. This can enhance JS and OC in order to lower their TI in medium-scale rubber smallholder sector in Kalutara District.

Keywords: Job satisfaction, Latex harvesters, Organizational commitment, Turnover intention

INTRODUCTION

Rubber (*Hevea brasiliensis*) is one of the popular plantation crops among smallholders in Sri Lanka and there are nearly 200,000 smallholders operating in all rubber growing Districts. The Medium-scale Rubber Smallholder Sector (MRSS) (4 ha - 22.5 ha) plays a key role in rubber production and contributes to 45% of the national rubber production (MPI, 2018). MRSS refers to the medium scale entrepreneurs in the sector which provides many types of job opportunities out of which the Latex Harvesters (LHs)/tappers are prominent among rural people in the rubber growing areas. The rubber tree is exploited by periodic excision of a thin shaving of the bark along a sloping groove placed spirally on the bark of the tree trunk to extract latex from latex vessels, which is the procedure known as harvesting (tapping). A latex harvester is a person who extracts latex from the rubber plant. Although latex harvesting/tapping is not a white-collar job, which is considered as the backbone of the rubber industry, as latex extraction is the initial step of the manufacturing cycle of rubber products. Harvesting is a technically skilled job that should be performed efficiently according to the harvesting recommendations formulated by the RRISL, to obtain the potential yield from a rubber plant and also to protect the rubber tree to get an optimum economic result over the total lifespan of the tree. The LHs are paid in a daily, monthly or share basis. Reference not necessary.

It is evident that 38% of the harvestable holdings were not harvested (4,981 ha) due to the turnover of LHs, in the medium-scale rubber smallholder sector in 2018 (MPI, 2018). In Kalutara District, an extent of 1, 323 ha of harvestable lands were abandoned due to the turnover of LHs and it is 1,502 when considering the number of holdings in 2018 (MPI, 2018). Shortage of LHs leads to the abandonment of harvestable rubber lands which are at the apex of their economic prosperity. Therefore, this issue makes a greater impact on the country's economy as rubber latex has to be imported for usage in local rubber industries. Hence, it is essential to find the factors that influence the turnover of LHs from the MRSS. Therefore, it is necessary to investigate the reasons for LHs turnover, in order to overcome these factors to attain development for a sustainable rubber sector. Turnover Intention (TI) is a topic of interest among management researchers. The most of empirical studies in TI are focused on employees from the hotel industry, marketing, health and hospital institutions and professionals from public and private institutions in Asian countries (Khatri *et al*., 2001). In Sri Lanka, many studies have been conducted to identify the reasons for turnover in the garment sector (Rathnasooriya and Jayatilake, 2016). To our knowledge, no planned studies have been undertakento assess the reason for turnover of LHs in MRSS. The objective of the present study is to examine how job satisfaction and organizational commitment affect Turnover Intention (TI) among LHs in MRSS in Kalutara District in order to fill the research gap. Such findings are useful to policymakers in a view to develop the community of LHs for better performance of MRSS.

MATERIALS AND METHODS

The qualitative research method is used in the present study to examine the relationship between the independent variables and dependent variables.

Sampling techniques

All the District Secretariat (DS) divisions in Kalutara District were selected for the study. LHs were selected using the stratified random sampling technique. The minimum size of the sample was 231, representing 23% of the population at a 90% confidence interval using Rao soft web-based sampling calculator (http://www.raosoft.com/samplesize.html). Stratification was done based on the geographical distribution of LHs in all rubber growing DS divisions in Kalutara, which is 8 in number. Twenty-three percent of Grama Niladari (GN) Divisions, where a higher number of LHs can be found within each DS division, were selected using the statistical sources. Then selection of the individual LHs was done so that, the survey sample (23% of LHs of each GN division) was randomly selected based on the number of LHs in each GN Division.

Data collection

Both primary and secondary data were collected for this study in 2020. The cross-sectional pre-tested questionnaire survey was carried out to gather information from LHs based on the objectives of the study. The key socio-economic factors and measuring items of Job Satisfaction (JS) and Organizational Commitment (OC) were included in the questionnaire. A structured direct interview schedule was used in gathering data from LHs, by the researcher himself.

Literature review and hypotheses development

Turnover is the voluntary and involuntary permanent withdrawal from an organization. Thus, "turnover" is the ratio of the number of organizational members who have left during the period being considered divided by the average number of people in that organization during the particular period (Alias *et al*., 2018). There were many predictors namely workload, work autonomy, promotion opportunities, employee empowerment and management styles and some socio-demographic factors namely younger age, inexperience and fewer years of the job which have an impact on turnover (Hayes, 2009). TI is the likeliness of an employee to leave the current job and willingness of an employee to leave his or her current organization (Chang *et al*., 2013). Lack of motivation, promotion and performance in the workplace causes the employee to quit the job and leave the organization (Bhayo *et al*., 2017). There are two categories of turnover; voluntary and involuntary (Alias *et al.,* 2018). Voluntary turnover is the situation that an employee quits the organization intentionally while involuntary turnover is the situation that an employee quit the company unwillingly and was forced to resign from his or her position by the organization due to several factors such as poor performance, medical unfitness, etc. (Bebe, 2016). It is evident that turnover has a hidden cost and time for the organizations. There is a loss to the institution economically, when an employee leaves the organization, because of the opportunity cost, retraining cost and reselection cost (Cho *et al*., 2009). Factors that affect the TI of an employee have become increasingly complex which is proven by the literature. Previous studies have confirmed the link between organizational citizenship behaviour (Nadira and Tanova, 2010), OC (Rai, 2013) and organizational justice (Rai, 2013) and TI in different sectors. Past studies related to TI have shown that OC and JS are considered as two important antecedent variables that affect the TI of employees (Karsh, *et al*., 2005). In fact, the findings of empirical studies on the relationship between OC, JS and TI have confirmed that the two variables have significantly negative effects on TI (Parker and Kohlmeyer, 2005). The salary level of employees has a significantly positive effect on TI (Ghiselli, *et al*., 2001). There is a positive relationship between the job stress and TI of employees (Sewwandi and Perere, 2016). However, no efforts have been made to study these factors affect the TI of the latex harvesters the MRSS in Sri Lanka.

Job Satisfaction

There are many definitions for JS that represent an individual's view and attitude towards the job (Salem *et al*., 2016). The definition of JS includes factors that can be grouped into four areas: economic aspects of work, interpersonal relationships, activities and tasks and working conditions. The factors affect JS are numerous and complex in relation to each other. There are three major types of causes which affect the JS of a person; Psychological, physiological and environmental conditions (Zalewska, *et al*., 2001). Studies have confirmed that the salary level has a significantly positive effect on organizational commitment (Folger and Konovsky, 1989), as well as on turnover intention (Ghiselli *et al*., 2001). It is apparent that the effect of work environment, salary level and co-worker relationships are important for turnover intention. Although most studies have shown a significant negative correlation between JS and TI (Rahman at al., 2008) found a moderate relationship between JS and TI. Nevertheless, among all the possible factors that affect job satisfaction, the most studies classify factors such as work environment and co-worker relationships are the most influential (Robbins, 2003).

Therefore, the first hypothesis was proposed as follows;

H1: JS is negatively related to TI.

Organizational Commitment

OC is a psychological state of an individual, that connects employees to their organization (Meyer *et al*., 1993) and employee's commitment to the organization (Porter *et al*.,1974). OC is an attempt of the employee to define and involve himself in the organization and there is no desire to leave (Sari, 2013). There are three components of OC including affective commitment, normative commitment and continuance commitment (Kreitner and Kinicki, 2012). Affective commitment is an emotionally based psychological state that drives employees to stay with a particular organization out of love or affection due to the result of positive past work-related behaviour (Velickovic *et al*., 2014). Continuance commitment refers to the decision of a person to stay with an organization based on weighing the cost associated with leaving the company (Meyer *et al*., 2002). Normative commitment is the feeling of retaining the membership of a particular organization is the right thing to do, when an employee stays in an organization with a sense of obligation and responsibility (Meyer *et al*., 2002). Morrison (2004) studied and showed that OC is negatively correlated with TI. According to the above literature review; the second hypothesis was as follows;

H2: OC is negatively related to TI.

Conceptualization of the study variables and their relationships

According to the theoretical framework of Price's turnover model (Price,1997) and literature cited (Salem *et al*., 2016), adoption in the local application of the MSSs can be conceptualized as presented in (Fig. 1).

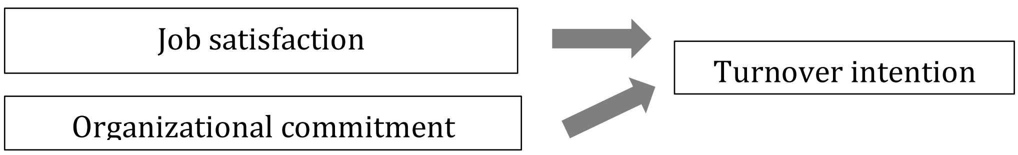

Figure 1: Conceptual Framework of the Study

Measurement of variables

The TI was the dependent variable and JS and OC were independent variables in this study. Slavitt's index of work JS (Slavitt *et al*., 1978) was applied to measure JS which consisted of 32 items in six subscales, that were autonomy, salary, interactions, administrative requirements, business requirements and level of a professional job. The Cronbach's α value was 0.92 for both the original scale and the version used in this study. The OC scale consisted of 18 items in three subscales that were, affective commitment, normative commitment and continuance commitment which were used to measure the OC (Meyer and Allen, 1991). The Cronbach's α value for the original scale was 0.86 (Olusegun, 2013). The TI was measured with 8 items developed by Viator, 2001. The Cronbach's α value for the original scale was 0.86 (Viator, 2001). Based on a five-point scale where, 1=strongly disagree and 5=strongly agree, participants were allowed to rate their degree of agreement towards JS, OC and TI.

Data analysis

The Cronbach's alpha (α) and Composite Reliability (CR) were assessed to measure the reliability and validity of items respectively, to cover the Convergence Validity (CV) (Hulland, 1999). The Average Variance Extracted (AVE) was assessed to measure the Discriminant Validity (DV) of items. Descriptive analysis was used to find the demographic variation. Pearson Correlation and multiple linear regressions were used to test the hypotheses.

RESULTS AND DISCUSSION

Demographics of the sample

The majority of the LHs were females (78%). Table 1 shows the age structure of the LHs. The age of LHs varied from 19 to 71 years. The majority of LHs belonged to the age category of 46-55 years. Nearly 9% of the respondents were above 65 years, while only 30% were found below 35 years. However, the young age (<35 years) category was not prominent in the study area, and it differs from the study carried out in Moneragala District. The most of younger generation (<35 years) in Moneragala is employed as LHs due to a lack of job opportunities (Wijesuriya *et al.*, 2008). The attraction of the younger generation must be directed to the smallholder rubber sector, mainly as LHs, so that the sustainability of rubber farming is ensured.

Table 1: Age structure of the latex harvesters.

Age structure of the farmers (years)	Percentage
<35	30
36-45	18
46-55	38
56-65	05
>65	09
Range	19 - 71

No one obtained higher education (diploma and degree level), and 1% of LHs had not attended school. Further, only 4 % of LHs had attended tertiary level education (GCE A/L). The average harvesting extent was 0.7 ha/day (approx. 350 trees). This figure seems reasonable and manageable to maintain the sustainability of the cultivation. The majority of LHs (58 %) have achieved more than ten years of work experience as a latex harvester with an average of 11 years. The average number of working days per week was four days.

The LHs were paid under two main categories; namely, monetary (96%) and non-monetary (4%) paying system as 50% sharing of the rubber production, 58% of LHs were paid on a daily basis whereas about 38% of them on a monthly basis. The non-monitory benefit was transformed into a monitory value varied from LKR 200-850, with a mean of 75 LKR/day. The LHs got a daily income as wages ranging from LKR 375-680, and the mean was LKR 560. Dissanayake *et al.*, 2014 highlighted that LHs were not satisfied with their wage rates. The mean wage rate was SLR 17,728 per month which varied from SLR 10,750 - 27,500. Nearly half of the LHs (54%) had not participated in any rubber related training programme.

Descriptive statistics, reliability, validity and discriminant validity of items

Table 1 shows the results of the reliability, validity and discriminant validity (DV) of items. The α values ranged from 0.79 to 0.85, which were above the acceptable threshold of 0.70 (Hair and Anderson,1998) (Table 2). CR values of all items exceeded the recommended level of 0.7 (Hair and Anderson,1998) (Table 2). According to the α (>0.07) and CR (>0.7), which were greater than standard values, it was indicated that the questionnaire had high reliability and validity, also it was indicated that the items of the questionnaire had a satisfactory CV, as recommended by Sarstedt *et al*., 2014. The AVE was within the range between 0.538 and 0.697 and the AVE of all items exceeded the recommended level of 0.5 (Sarstedt *et al*., 2014) (Table 2). Table 2 shows the descriptive statistics of the TI, OC and JS.

Table 2: The results of reliability, validity and discriminant validity of items

Item	Cronbach's alpha	Composite reliability	Average variance extracted
TI	0.851	0.740	0.588
OC	0.832	0.814	0.687
JS	0.815	0.645	0.538

Source: Survey, 2020

Interrelations between variables

The results of descriptive statistics of items are shown in Table 3. The mean scores of JS and OC were below the mid-point of 5-point Likert at 2.16 and 2.52, respectively. It was shown that LHs in MRSS displayed a low level of JS and OC within the organization. LHs have a high level of TI with a mean score of 4.53. Therefore, it was confirmed that all the respondents have a higher level of TI in MRSS.

Table 3: The Descriptive statistics of items

	JS	OC	TI
Mean	2.161	2.525	4.590
Standard Error	0.072	0.073	0.114
Standard Deviation	0.663	0.653	0.191
Sample Variance	0.439	0.426	0.282
Minimum	1.333	1.750	1.000
Maximum	4.768	4.877	5.000

Source: Survey, 2020

Correlation analysis

Table 4 shows the correlation analysis between all variables for the participants in the study. OC (r = -0.272) and JS (r = -0.497) were negatively correlated to the TI at a 0.01

significant level. However, there was a positive correlation between OC and JS (r = 0.385) at a 0.01 significant level.

Table 4: Inter-correlation between variables

	TI	OC	JS
TI	1		
OC	-0.272**	1	
JS	-0.497**	0.385*	1

Note: **Statistically significant at 0.01
Source: Survey, 2020

Multiple Regressions

Table 5 summarizes the results of the regression analysis, with respect to the significant determinants of turnover intention. This model is significant at 0.001. The 76 % of TI can be attributed to the variables namely; JS and OC. The JS (β = -0.425, p = 0.000<0.05) was found to have the highest impact on TI. The second highest impact on TI was made by the OC (β = -0.219, p = 0.011<0.05).

Table 5: The Results of Regression Analysis

	Standardized Coefficients	t	Significance
OC	-0.219	- 2.585	0.011
JS	-0.425	- 0.325	0.046
R^2	0.779		
Adjusted R^2	0.764		
Sig	0.000		
Durbin Watson	1.892		

Source: Survey, 2020

Hypothesis 1 which stated that the JS was negatively related to TI is verified by the findings of this research. The JS had a negative correlation with TI as it was verified similarly in the previous research (Khatri *et al*., 2001). This suggests that LHs with high JS levels have a low level of TI. Gunarathne *et al*., 2018 discovered that the level of the JS of LHs was low, with many factors affecting namely; low salary and work environment. Therefore, the management of MRSS should maintain those factors at appropriate level to improve the JS. It will help to lessen the TI of LHs.

The results of correlations in Table 3 have provided modest support to hypothesis 2 which states that the OC was negatively related to TI. Moreover, other studies have confirmed that the salary level has a significantly positive effect on OC (Folger and Konovsky, 1989), as well as on TI (Ghiselli *et al*., 2001). It seems that the effect of the work environment and salary level of the LHs in MRSS is important to TI. The salary level of the LHs was the lowest, comparing the employees of other industries (Gunarathne *et al*., 2018).

RECOMMENDATIONS AND CONCLUSION/S

This study concludes that the job satisfaction and organization commitment were the most influential predictors of turnover intention in medium-scale rubber smallholder sector. In this regard, the organization has to be more proactive in dealing with the job satisfaction and organization commitment of the employees at the workplace to avoid the feeling of intention to leave and find another job. Also, it is implied that serious efforts must be taken to formulate an appropriate policy in the organization to ensure the existence of employee well-being particularly among women workers. Feasible efforts must be made for the consideration of introducing easy methods for latex transporting and safety from animals and environmental hazards. It is suggested that future research should consider investigating other possible variables or predictors that influence the turnover intention of the latex harvesters in medium-scale rubber smallholder sector. And also, three strategies; Enhancing the social recognition by introduction of National Vocational Qualifications (NVQ), Introduction of continuous rewarding system (Monetary and non-monetary) and Human resource development programmes with motivational approach are suggested to reducing the rate of turnover intention of latex harvesters. These findings also help the management of medium-scale rubber smallholdings and policymakers to establish a better human resource management practice.

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CURRENT GEOGRAPHICAL DISTRIBUTION OF THE COCONUT WHITEFLY INFESTATION IN SRI LANKA AND THE EFFICACY OF INSECTICIDES TO CONTROL THEM

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ABSTRACT

A noticeable high infestation of whitefly species was observed in coconut in Sri Lanka 2019 and it was spreading across the country. At present, the infestation is present with varying degree in Gampaha, Colombo, Kegalle, Kandy, Kalutara, Galle, Matara, Puttalam, Kurunegala, Matale, Hambantota and Badulla districts.

Four species of whitefly: Aleurodicus rugioperculatus Martin (Rugose Spiraling Whitefly), Paraleyrodes minei Quaintance (Nesting whitefly), Aleurotrachelus atratus Hempel (Palm-infesting whitefly) and Aleurodicus dispersus Russell (Spiraling whitefly) are found in the infestation together with several species of Encarsia parasitoids including E. guadeloupae. Whitefly infestation results in yellowing of coconut fronds, and growth of sooty moulds and the infestation may affect the coconut yield as well. As the whitefly infestation was spreading rapidly, recommending control measures was urgently needed. The objectives of the present study were to determine the geographical distribution of whiteflies in coconut in Sri Lanka and to identify suitable synthetic and botanical pesticides to control the whitefly in coconut in Sri Lanka.

The presence of whiteflies in coconut in different geographical locations was studied in random surveys carried out during 2019-2022. Efficacies of synthetic insecticides and botanicals were determined in field experiments conducted in several locations.
Whiteflies are present in many geographical locations mainly in Gampaha, Colombo, Kegalle, Kandy, Ratnapura, Kurunegala, Kalutara, Matara, Galle, Ampara, Hambantota, Matale, Puttalam and Badulla. Spraying of Thiomethoxam (3g in 10 l), Carbosulfan 200 g/l SC (20ml in 10 l) and Chlorantraniliprole 20% +Thiamethoxam 20% (2.5g in 10 l) and the neem oil (10g) and soap (5g) in 1 l of water were found to be effective controlling the whitefly upto 89%. Therefore, the above insecticides at the rates given were recommended to control whiteflies in coconut in Sri Lanka. However, the synthetic insecticides are recommended to newly infested areas and the coconut nurseries, while neem oil-based insecticide is recommended to any infested areas to safeguard the buildup of natural enemies in the field.

Key words: Chemical control, Coconut, Encarsia, Whiteflies

INTRODUCTION

Pests and diseases are among the major threats to global agriculture as they contribute to significant crop losses in many important crops. Among the major pests of crops, whiteflies are highly invasive and has a wide host range including vegetables, fibre and ornamental crops (Lu *et al.,* 2019). Whitefly adult females lay eggs on the underside of leaves. Emerging nymphs undergo four instars and then pupate on leaves. Whiteflies are sap-sucking hemipterans that damage the host plant directly through their feeding. They also cause considerable indirect damage through vectoring a number of devastating viruses and by secreting large amounts of honeydew, which stimulates the growth of sooty mould that interferes with light absorption during photosynthesis (Taravati & Mannion, 2016).

Whiteflies are known to infest coconut in many countries since 1846 (CABI, 2022). *Aleurodicus cocois* Curtis (coconut whitefly), *A. rugioperculatus* Martin (rugose spiraling whitefly), *Paraleyrodes minei* Quaintance (Nesting whitefly), *A. dispersus* Russell (Spiraling whitefly) and *Aleurotrachelus atratus* Hempel (Palm-infesting whitefly) are among the major whitefly species that attack coconut worldwide. Almost all of them are invasive and spread from infested areas/countries to uninfested areas/countries through infested planting materials and the wind.

Adult females of whiteflies lay eggs on the underside of the coconut leaflets. The immature stages live on the underside of the leaflets feeding on the plant sap. In severe whitefly infestations, they migrate to the other plant parts in the coconut crown including inflorescences, peduncle and exocarp of the fruits of coconut which could eventually lead to reduced palm yield.

Whiteflies have been observed in coconut plantations in Sri Lanka at very minute infestations. However, since 2019, it is causing havoc in many coconut growing areas of the country. It was first reported as an outbreak in Kegalle district in Sri Lanka. Since then, it has spread to many coconut growing areas mainly in the wet and intermediate-zones. Though the whitefly was previously considered a minor pest of coconut, it has now become a major pest of coconut in Sri Lanka.

Due to tall stature and as most of the whitefly infestations in Sri Lanka are occurred in urban areas and home gardens, controlling the whiteflies in coconut has become a challenge, as the use of insecticides to control the pest is practically not feasible and unsafe to the humans, domestic animals and the environment. Therefore, as with many other coconut pests, a holistic approach is needed to control the whiteflies in coconut. Though many sustainable methods to control whiteflies of coconut *viz* biological control, mechanical control, semiochemical based methods etc. are available, each of them holds their own pitfalls when an alien pest is suddenly introduced. For instance, it takes a considerable time for any natural enemy population to build and one cannot solely depend on them to defend against high populations of alien whiteflies. Mechanical methods (jet water spraying) are not always economically or practically feasible with a crop like coconut. Semiochemical-based management methods are sustainable but finding such a method for a particular whitefly species involves extensive and long-term laboratory research; hence, it does not provide a rapid solution. Controlling whiteflies using chemical methods on the other hand provides a rapid solution compared to the above. However, it does not provide a long-term protection against whiteflies due to resistance development and their harmful effects on the environment. In Sri Lanka, as whitefly infestations are relatively new in coconuts, control measures are not recommended. Moreover, it is not clear the geographical distribution of the whiteflies in coconut in Sri Lanka.

The objectives of the studies reported in this paper were to identify the geographical distribution of the whiteflies in Sri Lanka and to evaluate insecticides and botanicals to control the pest.

MATERIALS AND METHODS

Study on the geographical distribution and the current status of whiteflies in coconut

Extensive field surveys were carried out by the Coconut Research Institute of Sri Lanka (CRISL) during the past years (2019-2022) to study the distribution of whiteflies in coconut in Sri Lanka. Surveys in randomly selected coconut lands were conducted to identify the species, distribution and the natural enemies of whiteflies. As the whitefly infestations are highly scattered, it was not possible to follow a proper sampling technique. Hence, the samples were collected from coconut palms that showed visual symptoms of the whitefly damage and the number of palms in each sampling occasion varied highly.

Efficacy of different insecticides on whiteflies

Field experiments were conducted with coconut palms of different ages during 2019–2022 in Kegalle and Colombo districts of Sri Lanka. Synthetic insecticides listed below were tested as an immediate remedy for controlling the pest outbreaks (Table 1). Due to the urgency in controlling the pest when the infestation was limited to Kegalle, Gampaha and Kandy districts at the time of the initial outbreaks in 2019, laboratory tests were not conducted to determine the lethal dose values. Also, due to the same reason, a limited number of dilutions rates were tested in the field.

Experiment 1 where the insecticides were applied as a trunk injection, was conducted in a randomized complete block design (RCBD) with three blocks in different locations in Kegalle district. Four palms were allocated for each treatment in each block. Two coconut rows around each block served as guard rows in this experiment.

Prior to the experiment 2, a preliminary experiment was conducted with 2 doses of Carbosulfan 200 g/l SC (10ml in 10l of water and 20ml in 10l of water) and

Thiomethoxam (2g in 10l of water and 3g in 10l of water). The doses, 10ml in 10l of water and 2g in 10l of water of Carbosulfan 200g/l SC and Thiomethoxam respectively did not give a substantial control of whiteflies (Aratchige, unpublished data). Hence, in the experiment 2, those doses were not included in the treatments.

As the distribution of whitefly infested palms were highly scattered in the field and due to the high degree of dissimilarity of neighboring infested palms in the field where the use of RCBD in the experimentation needed large areas (which eventually bring unexpected variability in to the experiment), non-contiguous plots were used in the experiment 2 where insecticides were tested by spraying. 10-15 palms around each plot served as guard rows in this experiment. The experiment was conducted in Kegalle district.

In both experiments, pretreatment data (on the number of adult whiteflies and nymphs per 3 leaflets per palm) were collected. After the treatments, post treatment data on the above parameters were collected at 7-day intervals for 21 days. The leaflets were collected in the field and the number of adult whiteflies was counted *in-situ*. Then the leaflets were brought to the laboratory in plastic bottles and the numbers of immature stages of whiteflies were counted under a stereo zoom binocular microscope. The data were analyzed using analysis of covariance (using pretreatment data as the covariate) and the mean values were compared by Duncan Multiple Range Test (DMRT) using SPSS program, version 23 (SPSS 2015). Prior to data analysis, all data were square transformed.

The percent reduction in the populations of whiteflies (adults+nymphs) over the control was calculated using Henderson and Tilton's formula:

$$\text{Corrected \%} = \left(1 - \frac{\text{n in Co before treatment} \times \text{n in T after treatment}}{\text{n in Co after treatment} \times \text{n in T before treatment}}\right) \times 100$$

Where; n= whitefly population; T= treated; Co=control (Henderson and Tilton, 1955).

Table 1: Synthetic insecticides tested to control whiteflies in coconut

	Insecticide	Dilution	Rate per palm
Experiment 1 (insecticides were tested using trunk injection)	Chlorantraniliprole 20% + Thiamethoxam 20% WG	4g in 10l of water	50ml
	Thiomethoxam	4g in 10l of water	50ml
	Buprofezin 10% WP	5g in 10l of water	25ml and 50ml
	Buprofezin 250 g/l SC	Undiluted	20ml and 40ml
	Carbosulfan 200 g/l SC	Undiluted	20ml
	Profenophos 500 g/l EC	Undiluted	16ml and 32ml
	Control (water)	-	50ml
Experiment 2 (insecticides were tested using spraying on to the abaxial surface of the infested leaflets)	Chlorantraniliprole 20% + Thiamethoxam 20% WG	2.5g in 10l	-
	Thiomethoxam	3g in 10l of water	-
	Carbosulfan 200 g/l SC	20ml in 10l of water	-
	Control (Water)	-	-

6-10l of the solution was needed to spray each palm, depending on the size of the canopy. Power sprayers were used to spray the insecticides and water (control).

In the 3rd experiment, a botanical pesticide mixture which consists of commercially available neem oil and soap powder was tested in a preliminary experiment. In a previous study, an experiment with different combinations of neem oil, soap powder and water showed that the mixture which contained 10ml of neem oil and 5g of soap powder in 1l of water gives the highest control in coconut whitefly (De Silva, Unpublished data). Therefore, only this mixture was further tested in the present experiment. Neem oil-soap mixture with the above combination was prepared using water as the solvent and sprayed on to the abaxial surface of leaflets by direct spray method using a modified knapsack sprayer. Approximately 6l of the solution was necessary to spray a palm in each spraying occasion and the spraying was repeated at 2-week intervals. The treatments include T1: Mixture of neem oil (10ml) + soap powder (5g) + water (1l), T2: Spraying of water, T3: Unsprayed control.

In this experiment data on the number of whiteflies in different treatments was not counted. Instead, the total number of fronds and the number of infested fronds in each treated palm was counted prior to commence the spraying and at 14 days interval thereafter. At each sampling occasion, treatments were applied to the palms. Percentage of the intensity of damage on palms were calculated using the following formula (Elango *et al.,* 2019).

$$Intensity\ of\ damage\ \% = \frac{Number\ of\ fronds\ infested/\ Tree}{Total\ number\ of\ fronds\ observed} \times 100$$

In all three insecticide experiments, the efficacy of them were not evaluated on different whitefly species (species identification was not done) due to practical difficulties.

RESULTS AND DISCUSSION

Geographical distribution and the current status of whiteflies in coconut

Initially, the whitefly infestation in coconut was observed in 2019 in a localized manner in Kegalle district. Later on, the whitefly infestations were spread to Gampaha, Kandy, Kurunegala and Ratnapura districts. The populations came down with the monsoon rains in the latter part of 2019. However, in 2020, when the country was locked down due to COVID-19, the population of whiteflies increased dramatically while spreading fast to Colombo and Kalutara districts. In 2021 and 2022, the whitefly infestations were reported from other coconut-growing districts of the country; Galle, Matara, Hambantota, Puttalam, Ampara, Matale and Badulla. The infestations are severe in Gampaha, Kegalle and Colombo districts, moderate to severe in Kurunegala and Kalutara districts and mild to moderate in other districts. So far, whitefly infestations have not been reported from the districts in the Northern Province, Eastern Province, North-Central Province and Moneragala and Nuwara Eliya districts.

Whitefly populations are more severe on the lower whorls than on the middle and upper whorls of the coconut and king coconut palms. All the stages of coconut and king coconut palms are susceptible to whitefly infestation. In Sri Lanka, king coconut and yellow dwarf coconut varieties were more susceptible to whitefly infestation. Similarly, *A. rugioperculatus* was reported on both tall and dwarf palm varieties, with a severe infestation on dwarf varieties (Mondal *et al.,* 2019, Alagar *et al.,* 2020).

Species of whiteflies observed in Sri Lanka

Four species, namely, *Aleurodicus rugioperculatus* Martin (Rugose Spiraling Whitefly), *Paraleyrodes minei* Quaintance (Nesting whitefly), *Aleurotrachelus atratus* Hempel

(Palm-infesting whitefly) and *Aleurodicus dispersus* Russell (Spiraling whitefly) were observed in the surveys carried out during 2019-2022. In a previous study, Karunarathne *et al*. 2023 also confirmed the presence of these species in coconut in Sri Lanka. Later these species were confirmed using molecular methods (Dilrukshika *et al.*, unpublished data). During the surveys, different species of *Encasia* were observed in association with whiteflies of coconut. *E. guadeloupae*, one of the most effective parasitoids reported from other countries, was also observed in whitefly colonies in Sri Lanka.

Efficacy of insecticides on whiteflies

a. Efficacy of trunk injection of insecticides

None of the trunk injected insecticides significantly reduced the whitefly populations than the control (water trunk injected) (P=0.86, Table 2).

Table 2: Efficacy of different insecticides against adults and nymphs of whiteflies on coconut

Treatment	**Percent reduction of whiteflies (adults+nymphs) over control per leaf (mean ± SE)**			
	7 days after treatment	**14 days after treatment**	**21 days after treatment**	**Overall reduction**
Chlorantraniliprole 20% + Thiamethoxam 20% WG	10.1 ± 3.3	9.7 ± 3.8	10.3 ± 5.4	9.9 ± 3.7
Thiomethoxam	9.6 ± 2.7	12.1 ± 4.8	10.2 ± 4.7	10.9 ± 3.9
Buprofezin 10% WP	-11.2 ± 7.2	5.1 ± 3.2	4.7 ± 2.4	3.2 ± 1.3
Buprofezin 250 g/l SC	-10.5 ± 6.7	-10.6 ± 3.4	2.1 ± 1.1	3.3 ± 1.7
Carbosulfan 200 g/l SC	7.9 ± 3.5	7.5 ± 3.4	8.9 ± 3.2	6.2 ± 3.1
Profenophos 500 g/l EC	6.5 ± 2.1	6.5 ± 2.3	3.1 ± 1.1	3.0 ± 1.1

b. Efficacy of spraying of insecticides

Spraying of Chlorantraniliprole 20% + Thiamethoxam 20% WG (2.5g in 10l), Thiomethoxam (3g in 10l of water) and Carbosulfan 200 g/l SC (20ml in 10l of water) resulted in significant reductions in the whitefly populations (P=0.03). However, there were no significant differences among the whitefly populations in different treatments. All three insecticides showed 70-89% overall whitefly reduction compared to the control (Table 3).

Table 3: Effect of spraying of insecticides on the percentage whitefly reduction

Treatment	Percent reduction of whiteflies (adults+nymphs) over control per leaf (mean ± SE)			
	7 days after treatment	**14 days after treatment**	**21 days after treatment**	**Overall reduction**
Chlorantraniliprole 20% + Thiamethoxam 20% WG (2.5g in 10l)	50.1 ± 14.3	66.1 ± 16.9	77.8 ± 21.2	70.0 ± 17.1
Thiomethoxam (3g in 10l of water)	68.9 ± 12.1	79.8 ± 12.3	88.9 ± 13.2	86.2 ± 15.8
Carbosulfan 200 g/l SC (20ml in 10l of water)	72.1 ± 16.9	81.8 ± 16.0	86.7 ± 14.6	83.5 ± 16.5

c. *Efficacy of spraying botanicals*

Mean reduction of the whitefly damage intensity in different treatments are shown in Table 4. Irrespective of the sampling date, the highest mean percentage reduction in the damage intensity was recorded in the palms where neem oil and soap mixture was sprayed. The highest percentage reduction in the damage intensity (44%) was observed after the 4th round of spraying (60 days after the first spraying). In the treatment where only water was sprayed, a lower percentage reduction of the damage intensity (3.9-16%) was observed than the treatment in which neem oil and soap mixture was sprayed but it was higher than the unsprayed control where an increase in the percentage of damage intensity was observed during the experimental period (Table 4).

Table 4: Reduction of the damage intensity of whiteflies after each spraying

Treatment	Before starting spraying	Mean reduction of damage intensity (%)			
		After 1st spraying (14 DAFT)	**After 2nd spraying (28 DAFT)**	**After 3rd spraying (42 DAFT)**	**After 4th spraying (60 DAFT)**
T_1	67.9	10	18	25.2	44.1
T_2	65.8	3.9	10.2	15.9	16
T_3	69.9	-2.4	-6.4	-9.1	-14

T_1: Neem oil with soap mixture, T_2: water spray, T_3: control, DAFT= days after first treatment

The current whitefly incidence in Sri Lanka is greatly alarming due to being non-native and polyphagous. Though the actual reason for the current invasiveness of the whitefly infestation in Sri Lanka is not elucidated yet, the possible reasons include accidental introduction of the pest from a neighboring country, increased whitefly populations due to changes in the climate change and due to sudden population drop of natural enemies of the whiteflies. The whitefly infestation may accidentally disperse to other coconut growing areas of the country probably along different anthropogenic activities (transportation of seedlings) and by natural occurrences *viz* heavy wind (Mondal *et al.,* 2019). There is a risk of establishing them in non-infested areas in near future. Therefore, it is an urgent need to spray insecticides to coconut seedlings before transportation from palm nurseries, thereby preventing the spread of whiteflies into new areas of the country. Three selected synthetic insecticides [Thiomethoxam (3g in 10 l), Carbosulfan 200 g/l SC (20ml in 10 l) and Chlorantraniliprole 20% +Thiamethoxam 20% (2.5g in 10 l)] showed a good control of whitefly and therefore, were recommended to control whitefly in coconut in Sri Lanka. In addition, the neem oil (10g) and soap mixture (5g) in 1 l of water was also recommended. Currently, natural enemy populations are being increased in the whitefly infested areas. Synthetic insecticides cause several negative impacts including environmental contamination, harm to the humans and the beneficial insects and domestic animals. Moreover, indiscriminate use of synthetic insecticides can lead to the development of resistance of insects to pesticides. Therefore, the CRISL recommends spraying of neem oil and soap mixture into the already infested areas and synthetic insecticides into newly infested areas and the coconut nurseries. In this way, it is expected to reduce the whitefly populations while conserving the natural enemy populations and minimizing the spread of whiteflies into new areas.

In addition to the use of synthetic and natural insecticides, use of yellow sticky traps has also been recommended in Sri Lanka. Further, it is very important to practice a holistic approach where the pest is controlled using integrated pest management strategies and the palm vigor is improved through good agricultural practices such as proper use of plant nutrients and soil moisture conservation. Hence, the Sri Lankan coconut growers are advised to control the pest using either synthetic or natural insecticides while using good agricultural practices to improve the vigor of the palms and thereby, decrease the crop loss due to whiteflies in coconut.

RECOMMENDATIONS AND CONCLUSION/S

Four species of whiteflies and several species of *Encarsia* parasitoids were identified in coconut in Sri Lanka. *A. rugioperculatus* (Rugose spiralling whitefly) is reported for the first time in Sri Lanka and possibly it has been accidentally introduced in to Sri Lanka.

Thiomethoxam (3g in 10 l), Carbosulfan 200 g/l SC (20ml in 10 l) and Chlorantraniliprole 20% +Thiamethoxam 20% (2.5g in 10 l) were recommended for controlling whiteflies on coconut; particularly in seedling nurseries and newly infested areas in Sri Lanka. Neem oil-soap mixture is recommended for whitefly control in all coconut growing areas.

However, it is necessary to be cautious when using synthetic insecticides as they could negatively affect the natural enemies of whiteflies.

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