Clusia rosea (Gal Goraka), an Alien Invasive Species Used as Fuelwood for Tea Drying in the Maskeliya Region, Sri Lanka

H.M.G.S.B.Hitinayake[1], P.K.S.Chanaka[1], T.Sivanathawerl[1], K.Raveendran[2], and Mahendra Pieris[3]

[1]Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Peradeniya, Sri Lanka.
[2]Technology Division, Tea Research Institute, Talawakelle, Sri Lanka.
[3]Hapugastenne Estate, Maskeliya, Sri Lanka.
Email: gaminisbh@gmail.com

Abstract— *Fuelwood is the major source of energy for tea drying in Sri Lanka. High moisture content and presence of latex in the wood are the two main problems in using Cluisia as a fuelwood in tea drying. This study was carried out at Moussakellie tea factory and Hapugastenne estate in Maskeliya to evaluate Clusia rosea as a fuelwood species in tea drying. Two fuelwood combinations were evaluated by estimating Specific Fuelwood Consumption (SFC). Moisture content of Clusia wood were measured in relation to stem girth and methods of processing. Wood production of Clusia coppice managed under a six year rotation was measured.*

The study clearly shows that Clusia rosea is a suitable fuelwood species for tea drying. Clusia showed a higher energy value as inclusion of it in the fuelwood mixtures caused a significant reduction in the Specific Fuelwood Consumption (SFC). Clusia wood can be mixed up to 50% with wild wood for tea drying without causing deposition of latex on heat tubes by maintaining flue gas temperature above 100^0C. Results of the study also showed that splitting and peeling are effective methods in removing moisture from Clusia wood. The study also identified the relationship between moisture content and moisture loss with stem girth. The biomass production of Clusia is found to be comparable with common fuelwood species used in tea drying. The study also revealed some characteristics of Clusia that contributes to its invasive behavior.

Keywords— *Alien invasive species Clusia rosea, coppice management, latex in fuelwood and tea drying.*

I. INTRODUCTION

Tea industry is the largest industrial fuelwood consumer in Sri Lanka utilizing approximately 33% of the total industrial consumption (Haskoning, 1989;

Koneswaramoorthy *et al,* 2004). Fuelwood is used for generation of heat for withering green leaf and tea drying in Sri Lanka (De Silva, 1994; Gunasena and Mohamed, 1998). About 22.4 MJ of thermal energy or 1-2kg of fuelwood is required to produce 1kg of made tea (Mohamed, 1998). The quantity of fuelwood is dependent upon the type of wood, efficiency of the furnace and the drier, type of manufacture and waste heat recovery system. A fuelwood to made tea ratio of 1:1 can be considered as very satisfactory. However, the efficiency of most furnaces used in the tea industry are very low, only have 55-65%. *Hevea brasiliennsis, Eucalyptus grandis, Paraserianthus falcataria, Calliandra calothyrsus* and *Gliricidia sepium* are the main species of fuelwood used in Sri Lankan tea industry. These species possesses characteristics that are typical of fuelwood species such as high growth rate, high calorific value, low leaf: stem ratio, high coppicing ability and also good burning properties (NAS, 1980; Gunasena and Pushpakumara, 1998). However, increasing fuelwood demand for the tea industry is difficult to meet through the established species as remaining underutilized lands in the tea growing regions are not suitable for growing them due to low soil depth and high rockiness.

Clusia rosea grows as an evergreen shrub to large tree. It is a hardy plant and exhibits Crassulacean Acid Metabolism (CAM) (Lee *et al,* 1989). This is a photosynthetic mechanism which aids in conserving moisture. *Clusia rosea* is a tree that can grow on infertile rocky lands. It can even establish on wet mosses growing on rock surfaces. It is also known for high growth rate and high biomass production. It is commonly known as pitch-apple, cupey or autograph tree (Florida Native Plant Society, 2013). *Clusia rosea* is commonly identified in Sri Lanka as "*Gal goraka, Ambul gas, Gal idda*" in Sinhala and "*Pulichcha*" in Tamil. It is listed as

an invasive species in Sri Lanka (MMD&E, 2015). *Clusia rosea*, a member of the family *Clusiaseae,* is a terrestrial or epiphytic tree or shrub native to Mexico, Florida and Central America, the Caribbean and northern South America (Wright, 1868; Francis, 1994; Dehgan, 1998; Starr *et al,* 2003; Gilman and Watson, 2014). The growth habit of *Clusia* is that it produces a cluster of stems (stools) from its base.

Clusia has naturalized in certain up country areas (high elevations) in Sri Lanka (Pebotuwage *et al*, 2012). It is widely used as a fuelwood for tea drying and for domestic cooking by the local communities in the Maskeliya region (Hitinayake *et al*, 2012). They peel and split the wood to accelerate drying prior to use them in cocking stoves. The villagers use the *Clusia* roots to tie the bundles of fuelwood. *Clusia* poles are used for construction of temporary houses and also as fence posts. The leaves of *Clusia rosea* are used to feed the goats.

There are two problems of using *Clusia* fuelwood in tea drying. *Clusia* wood has a yellow-white, resinous latex (Gilman and Watson, 1993). Before the furnace get heated to higher temperature, the latex present in *Clusia* wood evaporates and get deposited on the metal tubes in the furnace that convey heat, also on other parts of the furnace and the drier, reducing their efficiency (Raveendran, 2015). High moisture content of *Clusia* wood is the other issue for using it as a fuelwood (Raveendran, 2015).

The objective of the present study was to evaluate *Gal goraka* (*Clusia rosea)* as a fuelwood species in tea drying. Hence, estimation of specific fuelwood consumption (SFC) of fuelwood mixtures involving *Clusia rosea,* method to minimize deposition of latex on furnace especially on tubes that convey heat and also on drier when using *Clusia rosea* as a fuelwood, to study the moisture loss of *Clusia rosea* in relation to the girth classes, drying period and method of processing and to evaluate the biomass production of *Clusia* coppice were identified as the specific objectives of the study.

II.   MATERIALS AND METHODS

This study was conducted during 2015 at Mousakelleie tea factory and Hapugastenne tea estate located in the Maskeliya region, Nuwara Eliya district. Both Mousakelleie tea factory and Hapugastenne estate are located in the up country wet zone at elevations 1372m and 1205m amsl, respectively. The mean annual rainfall in this area ranges between 2763-3517mm and average annual temperature is 20.4^{0}C (Anon, 2018).

Experiment 01: Specific fuelwood consumption (SFC) of fuelwood mixtures containing *Clusia rosea*

As said before when *Clusia* is used as a fuelwood in tea drying, the latex present in its wood will get deposited on heat conveying tubes and other parts of furnace reducing its efficiency. Hence *Clusia* is always used in combination with wild wood by the tea factories in the Maskeliya region as a means of minimizing this problem. Two fuelwood mixtures containing *Clusia* commonly used in the tea factories in the Maskeliya region were selected for evaluation under this experiment: 75% wild wood + 25% *Clusia* and 50% wild wood + 50% *Clusia*. Wild wood contains approximately 80% *Albizzia* and 20% *Calliandra*. These fuelwood mixtures were evaluated by estimating their Specific Fuelwood Consumption (SFC).

Drier output (kg of made tea per hour), fuelwood feeding rate (kg of fuelwood fed per hour), flue gas temperature and inlet temperature of the drier were measured. Specific Fuelwood Consumption (SFC) was estimated by dividing fuelwood feeding rate (kg/hr) by the drier output (kg/hr). During the experimental period efforts were made to maintain the flue gas temperature and drier inlet temperature at a constant range and also to maintain the fuelwood feeding rate normally practiced at the factory. It took one day to complete a replicate of a fuelwood mixture. Four replicates from each mixture was used in the experiment. After 4 days, heat tubes were examined to check whether the latex of *Clusia rosea* is deposited on them.

Data were analyzed by applying sample t-test using SAS package.

Experiment 02: Moisture loss from *Clusia rosea* in relation to the girth classes, method of processing and drying period

The experiment consisted of 24 treatment combinations due to three factors (stem girth class, method of processing and drying period) and their levels (4x3x2). The stems of felled trees were separated into four girth classes (4-8cm, 8-12cm, 12-16cm and >16cm). Two methods of processing that is peeling and splitting of wood were evaluated by comparing with the control (unprocessed wood). Moisture content of wood was measured at the time of harvesting and after four weeks in the storage shed. Samples were oven dried at 103$^{°}$C till they reach a constant weight (oven dried weight). Moisture content was measured using following formula:

Moisture content (%) =
$$\frac{\text{Initial weight (g)} - \text{Oven dried weight (g)}}{\text{Initial weight (g)}} \times 100\%$$

The experiment design was a three factor factorial completely randomized design. Mean separation was done using Least Square Mean separation method (LSM).

Experiment 03: Biomass production of *Clusia rosea*

Fuelwood production of naturally regenerated *Clusia rosea* stand managed under simple coppicing system on a six year rotation was measured. A plot of 4x5m was harvested to measure the biomass production. The bottom girth, top girth and the length of each stem were taken. The girth of stems ranged from 4-16 cm. Wood volume was measured using following formula:

$$\text{Wood volume} = \frac{(A1 + A2)\ L}{2}$$

Key: A1- Cross sectional area at the top of stem, A2-Cross sectional area at the bottom of stem, L-Length of the stem

After harvesting the stems in the selected plot, number of fruits and number of seeds were counted to understand the regeneration potential of *Clusia rosea*.

The experimental design was a single factor completely randomized design. Mean separation was done using Least Significant Difference method (LSD).

III.   RESULTS AND DISCUSSION

Experiment 01: Specific Fuelwood Consumption (SFC) of fuelwood mixtures consisting *Clusia rosea*

Fuelwood mixture 1 showed significantly high SFC when compared to the mixture 2. The SFC of mixture 1 and 2 were 1.02 and 0.84, respectively. Average fuelwood feeding rate for mixture 1 and 2 were 257 kg/hr and 203 kg/hr, respectively. High fuelwood feeding rate (high SFC) is an indication for low efficiency of the fuelwood mixture (i.e. it consumes relatively high quantity of fuelwood to produce a kilogram of black tea). The results also indicates that *Clusia* has got a higher energy value when compared to wild wood as the mixture 2 that contained higher proportion of *Clusia* wood showed a low SFC.

Average drier inlet temperature was 268^0F for mixture 1 and 266^0F for mixture 2. The inlet temperature was slightly low with mixture 2 as fuelwood mixture contained relatively high proportion of *Clusia*. Maintaining a high inlet temperature will be a challenge when proportion of *Clusia* is high in the fuelwood mixture. Average flue gas temperatures maintained at the ID fan (temperature of hot air near the blower fan) with mixture 1 and 2 were 108^0C and 110^0C, respectively. The study also showed that these temperatures were high enough to minimize the deposition of latex on heat conveying tubes when above two mixtures of fuelwood is used.

Experiment 02: Moisture loss from *Clusia rosea* in relation to the girth classes, method of processing and drying period

1. Moisture content at the time of harvesting

Heating value of wood is largely determined by its moisture content. Drying of wood increases the calorific value of most type of fuelwood from about 4000 kcal/kg to 6500 kcal/kg (Jayatunge, 2014). In order to get maximum fuel use efficiency and performance, fuelwood requires to be cut to a uniform length of about 30cm and a diameter of 15cm and to have a maximum moisture content of 15% (Jayatunge, 2014).

The results of the experiment shows that moisture content was significantly high (P=0.05) in girth class 4-8 cm when compared to other girth classes at the time of harvesting (Table 1). But the difference between girth classes 8-12cm (57.57%) and 12-16cm (56.49%) was non-significant. The highest moisture content was showed with the girth class 4-8cm (59.92%) and the lowest was with girth class >16 cm (53.58%). The highest moisture content was showed by the unprocessed wood in girth class 4-8cm and the lowest by the peeled wood in girth class 4-8 cm. This shows that moisture content is high when the wood is thin and also when the bark is intact. This relationship is largely determined by the presence or absence of the bark and the proportion of the bark in the wood sample. This is because the bark contains more moisture than the inner parts of the stem and also the proportion of the bark in a wood sample is higher when the stem girth is smaller.

When consider the methods of wood processing, differences in mean moisture content between peeled (52.64%) and split wood (58.49%) was significant (P=0.05), but the differences between split wood and unprocessed wood (59.54%) was non-significant (P=0.05). The differences in moisture content between unprocessed and peeled wood across all girth classes except girth class >16 cm is significant (P=0.05). As said before, the above differences are largely determined by the presence or absence of the peel, as peel contains more moisture than the inner part of the stem. Differences in moisture content among girth classes of peeled wood was non-significant (P=0.05).

Table.1: Moisture content (%) at the time of harvesting.

Girth class (cm)	Processing method		
	Unprocessed wood - Control	Split wood	Peeled wood
4-8cm	64.53±1.24[a]	64.17±1.20[a]	51.08±0.73[d]
8-12cm	61.24±1.52[b]	59.41±0.58[c]	52.06±1.05[d]
12-16cm	58.04±0.23[c]	57±1.41[c]	54.44±0.27[d]
>16cm	54.37±1.28[d]	53.4±1.42[d]	52.98±0.17[d]
Mean	59.54±4.12	58.49±4.28	52.64±1.41

2. Moisture content after four weeks from harvesting

Moisture content of *Clusia* wood varied significantly (P=0.05) after four weeks in storage in relation to girth class and method of processing (Table 2). The highest

moisture content was recorded in wood with girth class >16cm (34.83%) and the lowest was with class 4-8cm (21.08%). But the moisture content didn't differ significantly between girth classes 8-12cm (29.27%) and 12-16cm (32.53%). This shows that the rate of moisture loss from wood decreases with increasing girth.

Moisture content after four weeks in the storage differed significantly (P=0.05) when wood was processed differently. The highest moisture content was recorded with unprocessed wood (35.65%) and the lowest with wood stored after removing the peel (24.75%). Also, it was found that moisture content was significantly different (P=0.05) between unprocessed wood and split wood in relation to girth class. The highest moisture content was recorded by the unprocessed wood in girth class >16 cm and lowest moisture content by the split wood in girth class 4-8 cm. The differences between mean moisture content between split wood and peeled wood in girth class 4-8 cm and >16 cm were non-significant (P=0.05).

Table.2: Moisture content (%) after four weeks from harvesting.

Girth class (cm)	Processing method		
	Unprocessed wood-Control	Split wood	Peeled wood
4-8cm	28.44±1.40[b]	16.8±1.30[c]	18.01±0.86[c]
8-12cm	33.51±0.35[b]	32.24±0.93[b]	22.08±2.36[c]
12-16cm	39.65±1.07[a]	30.32±1.34[b]	27.64±0.61[bc]
>16cm	41±1.13[a]	32.2±5.65[b]	31.3±2.70[b]
Mean	35.65±5.43	27.89±7.26	24.75±5.62

3. Moisture loss after harvesting

Differences in moisture loss among girth classes during the first four weeks after harvesting was significant (P=0.05) (Table 3). The highest mean moisture loss (38.84%) was recorded with girth class 4-8 cm and the lowest (18.75%) with girth class >16 cm. This shows that when girth increases the rate of moisture loss was low.

Also moisture loss varied significantly (P=0.05) among wood that were processed differently. The highest moisture loss (30.6%) was recorded with split wood and the lowest (23.9%) with unprocessed wood. The moisture loss differed significantly between unprocessed wood and split wood in girth class 4-8 cm. The highest moisture loss was showed in split wood in girth class 4-8 cm. Moisture loss didn't differ significantly among different wood processing methods in girth class 8-12 cm. The lowest moisture loss was recorded with unprocessed wood in girth class >16 cm.

Table.3: Moisture loss (%) during the first four weeks after harvesting.

Girth class (cm)	Processing method		
	Unprocessed wood-Control	Split wood	Peeled wood
4-8cm	36.1±2.65[b]	47.37±0.09[a]	33.07±1.6[b]
8-12cm	27.72±1.86[b]	27.17±1.51[b]	29.99±3.42[b]
12-16cm	18.39±1.3[c]	26.68±2.75[b]	26.8±0.9[b]
>16cm	13.36±0.15[d]	21.19±4.2[c]	21.69±2.53[c]
Mean	23.89±9.42	30.6±10.83	27.88±4.82

Experiment 03: Biomass production of *Clusia rosea* in a coppice stand

A *Clusia* stand managed under simple coppice system on a six year rotation was clear felled (harvested) by cutting the stems at the ground level. The resulted stems (copse or rods) were sorted based on their average girth (Table 4). Majority of the stems resulted after coppicing the stools (stumps) were in the girth class 8-12 cm (9.8 stems per stool) followed by girth classes 4-8cm and 12-16cm. Also the stems of the girth class 8-12cm recorded the highest wood volume. Wood volume per stool with 4-8cm, 8-12cm and 12-16cm girth classes were 5830cm^3, 15842cm^3 and 6036cm^3, respectively (Table 4). In the *Clusia* stand there were about 4845 stools per ha. Hence, the total wood volume harvested from a hectare of *Clusia* coppice under six year rotation was 129 cubic meters and it is highly comparable with commonly used fuelwood species in tea drying. For example, fuelwood production of *Eucalyptus grandis* and *Pariserianthus falcataria* are 40-200 cu. m per ha and 30-50 cu. m per ha, respectively (NAS, 1980).

Table.4: Size of stems and wood volume resulted from harvesting a 4x5m plot in the Clusia coppice.

Girth class (cm)	Average Number of stems	Wood volume per stool (cm^3)
4-8cm	7.3	5830
8-12cm	9.8	15842
12-16cm	2.3	6036
Total	**19.4**	**26708**

In addition to aggressive growth rate which will enable the species to over compete the other species easily, the study also revealed some other important reasons underlying its invasive behavior. The seed production of *Clusia* was estimated. The average number of seeds per fruit and the average number of fruits per stool was 41.5 and 55, respectively and therefore, the average number of seeds per stool was about 2283. As mentioned above, there were 4845 stools per ha in the *Clusia* stand. Hence, about 11.06 million seeds are produced by a one hectare stand. This is in addition to prolific vegetative propagation ability of species where even a small piece of stem can get easily establish as a plant.

IV. CONCLUSIONS

The results of this study shows that *Clusia rosea* can be considered as a suitable fuelwood species for tea drying. The inclusion of *Clusia* in the fuelwood mixtures has decreased the Specific Fuelwood Consumption (SFC), significantly. The study also shows that *Clusia* wood can be mixed up to 50% with wild wood for tea drying without causing considerable problem due to the deposition of latex on heat tubes. This was achieved by maintaining flue gas temperature near to the blower fan above 100°C. It was found that splitting and peeling are effective methods to dry *Clusia* wood. The study also identified the relationship between moisture content and moisture loss with the stem girth. The biomass production of Clusia is found to be comparable with common fuelwood species used in tea drying. Further, earlier studies have showed that calorific value of *Clusia* is 4155 kcal/kg (Hitinayake *et* al, 2012) and which is well above the minimum accepted (3500 kcal/kg) for fuelwood species (Gunasena and Pushpakumara, 1998). The study also revealed some important characteristics of *Clusia* that contributes to its invasive behavior.

REFERENCES

[1] Anon. (2018). Climate-Maskeliya. Climate-Data.org. Available at: https://en.climate-data.org/location/1061541/ [Accessed: 15 June 2018]

[2] De Silva, W.C.A., (1994). Status of energy utilization by the tea industry in Sri Lanka, *Sri Lanka Journal of Tea Science*, Vol. 63: 36-57.

[3] Cheek, M.D. and Lalla, R. (2017). A description of the naturalized *Clusia rosea* Jacq. (Clusiaceae) populations in South Africa. *Bothalia* 47(1), a2229. Available at: https://doi.org/ 10.4102/abc.v47i1.2229 [Accessed 15 June 2018]

[4] Dehgan, B. (1998). Landscape Plants for Subtropical Climates. University Press of Florida, USA. 656pp.

[5] Florida Native Plant Society (FNPS), 2013, *Clusia rosea*. Available at: http://www.fnps.org/plants/plant/clusia-rosea [Accessed 15 June 2018].

[6] Francis, J.K. (1994). *Clusia* rosea Jacq., Cupey: *Clusia*ceae, *Clusia* Family. International Institute of Tropical Forestry, U.S. Department of Agriculture, Forest Services. 4pp.

[7] Gilman, E.F. and Watson, D.G. (2014). *Clusia rosea*: Pitch Apple. Cooperative Extension Service, Institute of Food and Agricultural Sciences, University of Florida, USA.

[8] Gunasena, H.P.M., and Mohamed, M.T.Z. (1998). Use of biomass energy in processing tea. The Tea Research Institute, Talawakele, Sri Lanka.

[9] Gunasena, H.P.M. and Pushpakumara, D.K.N.G., (1998). Selection criteria for fuelwood tree species.

[10] Haskoning, (1989). Energy Conservation in the Tea Industry of Sri Lanka. Haskoning Royal Dutch Consulting Engineers and Architects, 206pp.

[11] Hitinayake, H.M.G.S.B., Priyadarshana, G.V.U. and Mahendra, P. (2012). Potential of *Clusia rosea* (Gal Goraka) as a Fuelwood Species. *Sri Lanka Journal of Agricultural Sciences*. Vol. 49: 98-105.

[12] Jayatunge, N.G.P. (2014). Engineering aspects of tea processing (Revised edition). National Institute of Plantation Management, Sri Lanka. 130pp.

[13] Koneswaramoorthy, S., Mohamed, M.T.Z. and Galahitiyawa, G. (2004). Developing and evaluating solar energy techniques for tea drying. *Journal of National Science Foundation*. Vol. 32 (1&2): 49-60.

[14] Lee, H.S.J., Schmitt, A.K. and Luttge, U. (1989). The Response of the C_3 —CAM Tree, Clusia rosea, to Light and Water Stress: II. Internal CO_2 Concentration and water use efficiency. *Journal of Experimental Botany*. Oxford University Press Vol. 40, No. 211. pp. 171-179.

[15] MMD&E. (2015), Invasive Alien Species in Sri Lanka: Training Manual for Managers and Policy Makers. Biodiversity Secretariat, Ministry of Mahaweli Development and Environment

[16] Mohamed, M.T.Z. (1998). Use of biomass energy in processing tea. Proceedings of the ninth national workshop on multipurpose trees, MPTS Network of Sri Lanka, Kandy, Sri Lanka. pp. 152-163.

[17] NAS (1980). Firewood Crops: Shrubs and tree species for energy production. National Academy of Sciences. Washington D.C. 237pp.

[18] Peabotuwange, I., Bandara, I.N., Samarsinghe, D., Perera, N., Madawala, M., Amarasinghe, C. (2012). Range extension for *Duttaphrynus kotagamai* (Amphibia: Bufonidae) and preliminary checklist of herpatofauna from the Uda Mäliboda trail in Samanala nature reserve, Sri Lanka. Amphibian and Reptile Conservation 5: 52–64.

[19] Raveendran, K. (2015). *Personal communication*. Tea Research Institute, Talawakelle, Sri Lanka.

[20] Starr, F., Starr, K. and Loope, L. (2003). '*Clusia rosea*: Autograph tree'. United States Geological Survey-Biological Resources Div., Haleakala Field Station, Maui, Hawaii.

[21] Wright, C., (1868). A tropical air-plant. American Naturalist 2, 368–370. Available at: https://doi.org/10.1086/270263 [Accessed 15 June 2018].