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PROCEEDINGS OF THE 24th PROJECT EVALUATION AND MONITORING (PEM) SEMINAR 2020 & 2021

FRIM R&D: ADDRESSING FUTURE CHALLENGES

22–23 February 2022

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Editors

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Preface

Seminar on Project Evaluation and Monitoring (PEM) is an annual event held for researchers to present their findings from the project that was completed in the current year. It also provides a platform for discussing the issues, challenges, and opportunities in forestry research, and hopefully, it will spark collaboration between the divisions in FRIM. The researcher of the selected projects will present their findings in oral, montage, or poster presentations. The event organised by Research Policy and Planning (RePP) Branch planned for 2020 and 2021 was postponed to 22-23 February 2022 because of the COVID-19 pandemic.

There was a total of 70 and 77 projects completed in 2020 and 2021 respectively, however, due to the limited presentation slot and capacity constraints, only selected projects can be presented in the seminar. This year besides oral and montage presentations, posters were also included in the seminar to open up more opportunities for researchers to present their research findings. We try to accommodate the projects from various funders representing each R&D division in FRIM. This is the first proceedings of the PEM seminar containing the written versions since the first time the seminar was organised. The proceedings cover the upstream and downstream forestry research that includes topics in forestry and environment, forest biodiversity, forestry biotechnology, economic and social forestry, forest products, and natural products. A total of 51 articles were included in the proceedings.

Finally, we would like to express our gratitude and appreciation to all authors for their contributions to this publication. Many thanks go to all project leaders and researchers for their support and cooperation in the seminar. Special thanks go to top managements FRIM, Dr Ismail Hj Parlan (Director General), Dr Norwati Muhammad (Deputy Director General Research), Dr Noor Azlin Yahya (Deputy Director General Operational), and all division directors especially Dr Mohd Rosli Haron (Director Research Planning Division) for their support and encouragement. We hope that the proceedings will be useful, exciting, and inspiring especially for all FRIM researchers to continue producing excellent results and increase efforts in obtaining funding either nationally or internationally.

The Editors

FORESTRY, ENVIRONMENT & BIODIVERSITY

STUDY OF TIMBER EXTRACTION TECHNIQUES USING LOG FISHER ON THE FOREST ENVIRONMENT IN HILL DIPTEROCARP FOREST OF PENINSULAR MALAYSIA

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Timber extraction is an important activity in timber harvesting operations. Current timber extraction technique emphasizes the reduce impact logging (RIL) practices, which was introduced in 2010, and can be done with log fisher. However, there is no study on the effect of the log fisher technique on the forest environment that can verify it is a RIL practice. Therefore, this research aims to carry out the impact assessment of log fisher timber extraction techniques against the forest environment by looking at the residual stand damage, canopy opening, soil compaction, and water quality disturbance. A total of six sampling plots were set up in Compartment 63 Block A, Petuang Forest Reserve, Kuala Berang, Terengganu. Data for assessing the impact of timber extraction activities on the residual stand were collected in two phases: before harvesting and after harvesting operation within the same sampling plot. The canopy cover was measured using Gap Light Analysis Mobile Application. Impact on soil compaction was represented by bulk density, moisture contents, and porosity measurement after harvesting. Meanwhile, water quality disturbance was done by looking at the impact that occurs on water temperature, pH, dissolved oxygen, turbidity, conductivity, and sediment before, during, and after harvesting. Overall, the average mortality rate for all trees in the sampling plot was 18.43%. Damage to the residual stand also showed that most of the injuries occurred to the roots and canopy rather than the bark of the tree. Damage to the forest canopy also recorded that canopy openness increased by 15.73% and canopy cover index decreased by 3.65%. Soil compaction in skid trail recorded an increase of 0.05% for bulk density, an addition of 12.37% for moisture content, and a decrease of 1.73% in porosity. Water quality impacts mostly were recorded in Class I for temperature, dissolved oxygen, turbidity, conductivity, and total dissolved solids meanwhile Class II and III for pH measurement. This study found that the impact of timber extraction using the log fisher technique on the forest environment after harvesting is minimal. In terms of forest management and the development of forest heritage, this study continues to strengthen the implementation of the existing sustainable forest management practices with an emphasis on the minimum environmental impact that indirectly raises nation revenues and builds a better society. This study also assists contractors and forest managers in making better future decisions about the conservation of the forest environment.

Keywords: Log fisher, reduce impact logging, timber extraction, sustainable forest management

INTRODUCTION

According to the requirement of sustainable forest management (SFM), timber harvesting operations need to be conducted with minimum impact on the environment. Timber extraction activities are an important aspect in minimizing the environmental impact since machinery traffic and timber extraction activities caused a significant amount of damage to the residual stand, soil, and water quality and indirectly affect the volume growth for the next harvesting cycle. Most of these impacts have resulted from the crawler tractor extraction technique. Picchio et al. (2012) and Cudzik et al. (2017) stated that timber extraction activities would cause severe damage to the residual stand, especially for those that located near the skid trail with a crawler tractor technique. Excessive soil compaction and erosion that leads to water quality disturbance resulting from the crawler tractor technique were also reported by Laudon et al. (2011) and O'Driscoll et al. (2016). The impact of timber extraction activities is not only on the forest environment, but they inhibit the next harvesting cycle achievement in terms of volume growth (Wan Mohd Shukri et al. 2004; Samsudin et al. 2010). Moreover, the recovery rate of the residual stand is one of the main elements in determining SFM. Therefore, from all the reports found, research on the environmental impact of the log fisher technique was not available. In response to the lack of study on the use of log fisher and its impact on the environment, this research plan to carry out an assessment investigation for impact minimization of log fisher extraction techniques. This research is expected to mitigate some, or all of the problems noted above and continue to strengthen our SFM.

MATERIALS AND METHODS

Study Area

The study was conducted in Compartment 63 Block A, Petuang Forest Reserve, Kuala Berang in the western part of Terengganu as shown in Figure 1. The study area is 208 ha and is located between latitude 5°23'5.24" N to 5°22'24.58" N, and longitude 102°37'3.57" E to 102°38'40.85" E. Located at an altitude between 176 m to 871 m, the study area is characterized by sloping terrain conditions between 6.79° to 6.85°. The volume of trees allowed to be harvested for this operating area is 67.75 m^3/ha with 39.16 m^3/ha of which are from dipterocarp species, and the remaining 28.59 m^3/ha are from non-dipterocarp species. Extraction using log fisher is a technique that is fully used in this forest operation area. The study area has 284 m of skid trail alignment and a total of 44 temporary log yards.

Sampling Plot

Six sampling plots were set up before the timber harvesting operation take place (pre-felling) and measurement was taken before and after harvesting. The sampling plot was divided into 25 sub-plots of 10 m x 10 m as shown in Figure 2. Each sub-plot was marked with polyvinyl chloride (PVC) pipe and numbered at the bottom left corner. Plots were placed randomly in two different slope categories viz. 1) <20° (low slope), and 2) >20° (high slope). Each slope category was represented by three replication of sampling plots and must have at least two cutting trees in one plot to assess the logging damage.

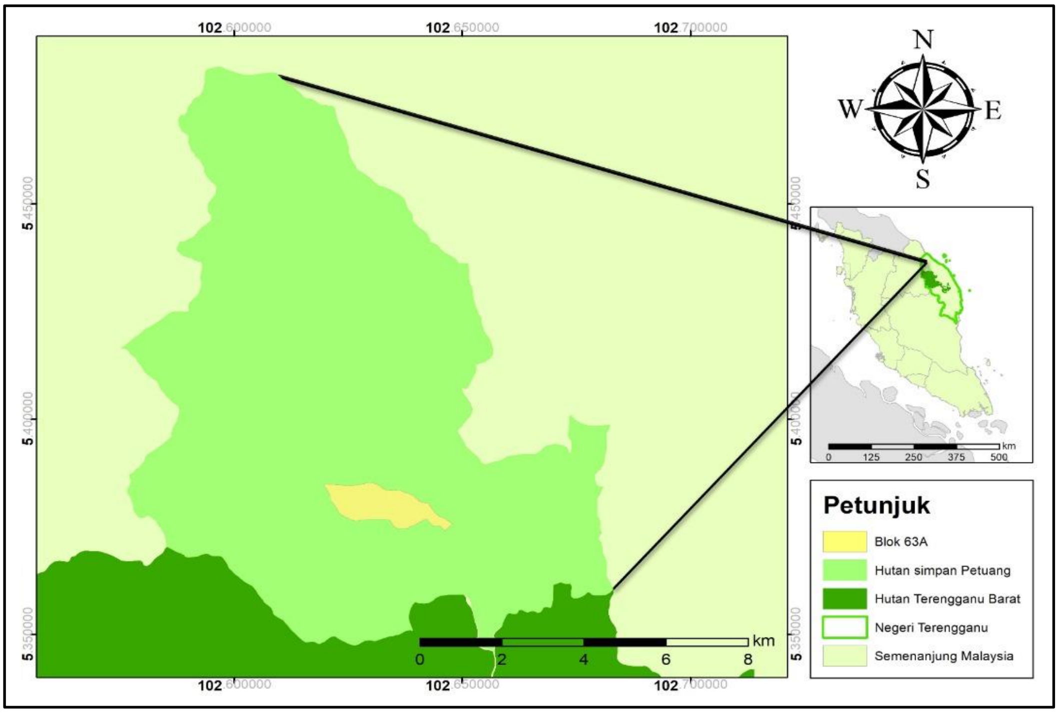

Figure 1 Location of the study area in the west part of Terengganu state

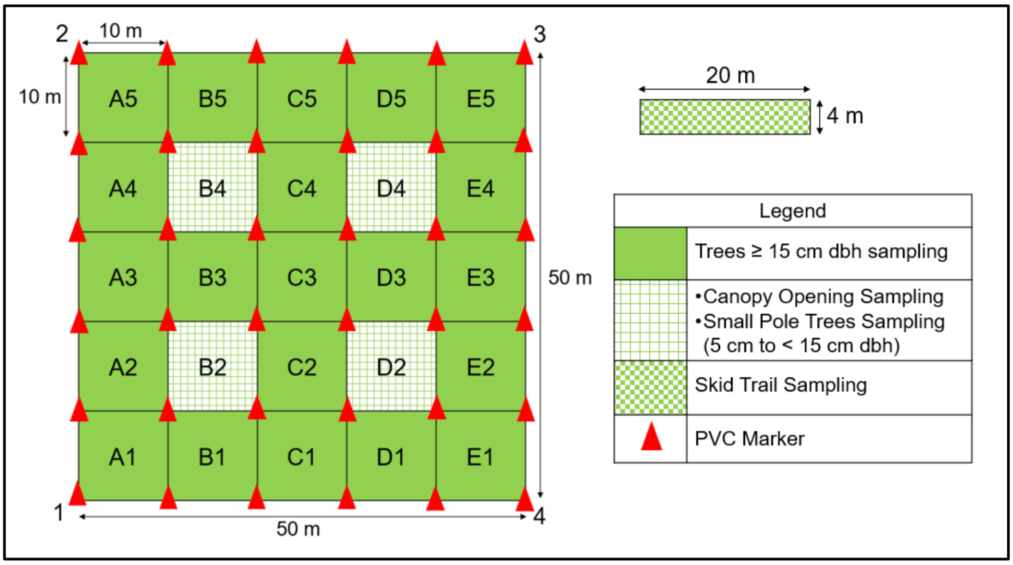

Figure 2 Sampling plot design

Data Collection

a. Impact on residual stand

Data for assessing the impact of timber extraction activities on the residual stand were collected in two phases: before harvesting and after harvesting operation within the same sampling plot. The parameters recorded before the harvesting operation served as control data, which was later compared to the impact on the residual stand after harvesting activities.

Data collected before harvesting activities were tree species, diameter at breast height (dbh), tree condition, tree number, location of the trees (x, y) within the sampling plot and canopy cover. Trees of ≥ 15 cm dbh (including the harvested tree) were measured within the main plot of 50 m x 50 m. Small pole tree sampling (5 cm to < 15 cm dbh) was measured within the sub-plots B2, D2, B4 and D4 as shown in Figure 2. Tree dbh measurements were done according to the forestry manual by Manokaran et al. (1990). The canopy cover was measured using Gap Light Analysis Mobile Application (GLAMA) (Tichý 2015) to determine the percentage of canopy cover for residual stand by taking a photograph that is downward facing the vegetation or define as fisheye to estimate canopy cover from hemispherical photographs. The canopy opening sampling was replicated at four points randomly in the plot as shown in Figure 2. Tree mapping was also conducted throughout the study area to find the residual stand position in the study area and illustrates the damage to the residual stand due to timber extraction activities.

b. Impact on soil physical properties

Data collections were carried out after the harvesting operation. Soil samples were collected from two series of the situation; 1) Along extraction trails and 2) At the platform, to examine the relationship between extraction technique and physical responses of soil. Soil samples were collected by using an Edelman hand augers sampler with a diameter of 70 mm. Soil samples were collected by carefully clearing all residue then drive hand auger to a depth of 5 cm from the top.

Soil bulk density, moisture contents and total pore spaces were determined for each sample by using standard laboratory procedures for disturbed soil samples. The soil samples were promptly weighted by using a weighing scale; they oven-dried at 110°C for 24 hours to remove non-structural soil water until the mass remains constant and reweighed for the dry weight (Ampoorter et al. 2007; Demir et al. 2007). The differences between net weight and dry weight were measured to the nearest 0.01 g.

c. Impact on water quality

Monitoring of water quality was conducted through in-situ (direct measurement in the field) and ex-situ (measurement at Forest Hydrology laboratory, UPM). The use of research equipment such as YSI Multiparameter and Turbidity meter is to measure the value of each water quality parameter in the field while sediment matter content was carried out at the laboratory. YSI multiparameter take four measurements of water quality i.e., temperature, pH, dissolved oxygen, and conductivity. Meanwhile, a turbidity meter was used to measure water turbidity. Water quality was monitored in three stages: before harvesting, during harvesting, and after harvesting. The concentration of suspended sediment was tested in the laboratory for the determination of total dissolved solids. Therefore, the study of water quality impact from log fisher extraction technique was done by looking at the impact or changes that occur in water temperature, pH, dissolved oxygen, turbidity, conductivity, and sediment.

RESULTS AND DISCUSSION

a. Impact on Residual Stand

Tree damage due to slope intensity

The increasing gradient of a slope contributes the most to damage size and the number of damages per tree as reported in Picchio et al. (2019). Overall, the average mortality for all plots was 18.43%. Meanwhile, the average mortality for the low slope was 18.21% and the high slope was 18.66%. Although the average mortality rate for the two slope categories is about 0.45%, tree harvesting on higher slopes causes harvested trees to fall and roll over other trees, causing death and damage. However, the use of log fisher can reduce the percentage of damage to the bark, roots, and canopy even when harvesting is carried out in high sloping areas.

Overall tree damage using a log fisher

Most of the findings in this study focused on residual stands of 30 cm dbh and above because these are the trees that have the potential to be harvested in the next round of harvesting. Trees of class 05 - 14.9 cm dbh recorded 14.88% mortality while class 15 - 29.9 cm dbh recorded 2% mortality. Trees of class 05 - 14.9 cm dbh recorded the highest mortality because harvested trees tend to fall and roll over on these small pole trees during felling and extraction activities. Trees of class 30 cm dbh and above showed 1.58% mortality while class 45 cm dbh and above, 50 cm dbh and above and 60 cm dbh and above each showed 1.21% mortality. Trees of class 75 cm dbh and above recorded the lowest mortality percentage of 0.62%. Damage to the residual stands also showed that most of the injuries occurred to the root and crown rather than the bark of the tree. The level of non-serious injuries (category 1) was overall below 0.14% where the injured trees could still survive to live until the next round of harvesting. However, the level of serious injuries (category 2) was overall below 0.39% where the injured trees were estimated to be unable to survive and eventually die before the next round of harvesting.

Coverage opening analysis

In general, there was forest canopy damage as recorded by the canopy openness which increased by 15.73%, and the canopy cover index decreased by 3.65%. A clear difference can be seen in sampling plots 2, plot 3, plot 4 and plot 6. This is because plot 3, plot 4, and plot 6 are in high sloping areas while plot 2 has large harvest trees.

The results of the analysis of the canopy cover opening prove that high sloping areas recorded the percentage of forest canopy damage compared to low slopes. High sloping areas recorded a canopy openness increased by 3.33% and canopy cover index decreased by 3.50%. Damaged forest cover increases as the slope in the harvesting area increases. This may be due to limited log control, which can more often roll on steeper slopes during tree felling and extraction activities.

b. Impact on Soil Physical Properties

Before harvesting, the average soil bulk density obtained was 0.98 g/cm³. After harvesting, for skid trail, the average soil bulk density was 1.03 g/cm³. For the platform, the average value obtained is 1.31 g/cm³. The value of soil bulk density after harvesting showed a slight increase of about 0.05% in the skid trail about 0.34% compared to the platform which recorded a significant increase in general. Low slope areas, on the other hand, show a higher soil bulk density than high slope areas because there are many felled trees in low slope areas, thus increasing the use of skid trail and log fisher movement on the platform.

The average soil moisture obtained before harvesting was 45.51%. After harvesting, for the skid trail, the average soil moisture was 57.88% meanwhile the average for the platform is 22.90%. Soil moisture before harvesting is lower because there is still a topsoil layer while the soil layer after harvesting is mixed topsoil and subsoil. The subsoil is usually wetter and provides a greater root-soil contact (Lipiec et al. 2003; Lipiec et al. 1993). In contrast to the soil moisture obtained on the platform because the soil is already compacted as recorded by the bulk density of the soil above.

The average porosity of the soil obtained before harvesting was 62.86%. After harvesting, for the skid trail, the average soil porosity was 61.13% meanwhile the average for the platform was 50.43%. As a result, the trend of water transparency to reach into the soil decreased by 1.73% for the skid trail while 12.43% for the platforms during the study.

c. Impact on Water Quality

For water temperature, it was found that all three sampling points recorded water temperature at an average between 23.94 to 22.62˚C. This is a common condition for river surface water. There were no significant differences between the monitored sampling points. The temperature in the river is according to the characteristic conditions of the forest and its environment.

In general, the average pH for the three sampling points ranged from 5.79 to 6.68. The pattern of change shows that all stations have a moderate pH value that is in Class II and III. Class I is between pH 6.5 to 8.5, Class II is between 6 to 6.5, and Class III is between 5 to 6. However, this situation is normal for forested areas especially logging territory based on soil characteristics that may be acidic rather than the occurrence of leaf and wood decay of plants.

The average dissolved oxygen concentration recorded was in the range of 7.85 to 9.66 mg/l. Class I of dissolved oxygen is more than 7 mg/l while Class II is between 5 to 7 mg/l and Class III was from 3 to 5 mg/l. Therefore, dissolved oxygen that was recorded in this study is relatively good for all phases of harvesting.

The average turbidity was in the range of 3.66 to 55.83 NTU. Class I turbidity was range between 5 to 50 NTU while Class II is more than 50 NTU. The highest value recorded was during the harvesting phase which was 55.83 NTU. This may be due to the occurrence of heavy rain before the data observations were performed, together with the surface runoff caused by harvesting activities.

The electrical conductivity readings for the three sampling points were quite consistent before, during, and after harvesting. The conductivity reading range was between 14.46 to 25.09 µs/cm. Class I and II of electrical conductivity was less than 1000 µS/cm while Class IV was more than 6000 µS/cm. Therefore, all measurements fell in the Class I category.

The average for total dissolved solids was in the range of 0.01 to 9.53 ppm. Class I of total dissolved solids was less than 500 ppm while Class II is 500 to 1000 ppm. Hence, the concentration of suspended sediment that was determined by the total dissolved solids was all recorded in Class I.

CONCLUSION

Based on the results obtained from this study, forest harvesting using the log fisher technique gives minimum impact on residual stand damage, forest cover, soil compaction, and water quality. Overall, the average mortality rate for all trees in the sampling plot was 18.43%. Damage to the residual stand also showed that most of the injuries occurred to the roots and canopy rather than the bark of the tree. Damage to the forest canopy also recorded that canopy openness increased by 15.73% and canopy cover index decreased by 3.65%. Soil compaction in skid trail recorded an increase of 0.05% for bulk density, an addition of 12.37% for moisture content and a decrease by 1.73% of porosity. Water quality impact mostly was recorded in Class I for temperature, dissolved oxygen, turbidity, conductivity, and total dissolved solids meanwhile Class II and III for pH measurement. This study assists contractors and forest managers for better future decision-making regarding forest environment conservation and higher learning institution in making significant improvements towards forest management and science ecosystem.

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VOLUME FUNCTIONS FOR SECOND GROWTH HILL DIPTEROCARP FOREST IN NEGERI SEMBILAN

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The need to have an accurate measure of tree volume is fundamental in forest management and administration as tree volume is widely used for estimating the productivity of a forest stand, as well as for the assessment of taxes and fines. In a moist tropical forest, a volume table has been recognized as the best approach to estimate volume especially due to some difficulties in tree measurements. Therefore, this study was carried out to develop volume functions for second growth hill dipterocarp forest in Negeri Sembilan using a non-destructive technique, and subsequently construct a local volume table. A total of 2,415 vigorous individual trees of > 15 cm diameter at breast height (dbh) were selected for measurement and were used in developing the functions for over bark timber volume. Unweighted and weighted volume equations were fitted by the method of least squares. The volume functions by all species and by two major species groups; Dipterocarp and Non-Dipterocarp, were derived from tree samples collected from second growth hill dipterocarp forests in Negeri Sembilan. Furnival's Index (FI) was used as the criterion for selecting the best fit regression functions for those three species groups. As a result, the selected volume functions for second growth hill dipterocarp forest in Negeri Sembilan are as follows:

All species, $V/D^2 = 0.0016017 - 0.0548980(1/D) + 1.0184491\,(1/D^2)$

Dipterocarp, $V/D^2 = 0.0011204 - 0.2255673\,(1/D^2)$

Non-dipterocarp, $V/D^2 = 0.001026 - 0.1947\,(1/D^2)$

Where, V is the tree volume (m^3 overbark) and D is the reference diameter or dbh (cm). These functions were found to estimate a merchantable tree volume and the aggregate standing volume that fit under the given study conditions. However, the applicability test of these functions is needed if they are to be applied elsewhere.

Keywords: Volume function, local volume equation

INTRODUCTION

Tree volume is one of the fundamental requirements in forest mensuration and management for providing estimates of volume needed to determine sustained yield and periodic increment. Volume information is also used by forest managers and logging contractors in assessing the commercial value of a forest stand and by the government for collecting taxes. Recognizing the importance of this parameter, it is crucial to have accurate and reliable estimates of tree volume. Currently, volume estimation used in operational inventories in Peninsular Malaysia is based on a generalized volume function that applies to the whole Peninsular Malaysia and all inland forest types. The function was developed by the Forestry Department of Peninsular Malaysia in the 1970s using the sample from lowland forests and is still being applied. However, most of these lowland forests have given way to agricultural development and the Permanent Reserve Forests for timber production are now confined mainly to the hill forests between 300 and 750 metres (m) altitude above sea level. In addition to that, it is predicted that in the next 5 to 10 years, all the primary production forests in Peninsular Malaysia are expected to be completely harvested, which states will start to harvest their second growth (logged-over) or second rotation forests. The existing volume functions are considered to be inapplicable or less applicable to second growth hill forests due to the different growth structures and characteristics, as well as the species composition of the second growth hill dipterocarp forests. Previously, the sampling approach adopted for the development of volume functions was through destructive sampling where trees are felled and measurements of diameters made directly on sections along the stems of the felled trees. This is difficult and costly. Currently, the demand for the forest to be managed intensively and sustainably for a variety of goods and services requires more accurate volume estimates based on single species or species groups, specific forest types, and localities. . This is necessary as different species have different growth patterns and varying shapes and thus will have different volumes even if certain characters such as diameter are similar. Similarly, trees in different geographical locations and ecological zones will also have different volumes even for the same species. It is thus pertinent that new volume functions that are applicable for localized condition and specific to species or species group must be developed. It has also been highlighted in the 38th Majlis Urusan Hutan dan Silvikultur (MAJURUS) where each Forest Management Unit (FMU) is preferable to have its own local volume table. Therefore, this study was carried out to develop volume functions using a non-destructive sampling technique and subsequently constructed the local volume table for the second growth hill dipterocarp forest in Negeri Sembilan.

MATERIALS AND METHODS

In this study, volume functions were developed for the second growth hill dipterocarp forest at Negeri Sembilan. Generally, the derivation of a volume equation to develop a volume table involved at least three distinct phases (Loetsch et al. 1973):

1. Measuring the volume of selected trees in a sample representing the population,
2. Establishing the relationship between the measurements taken on the tree and its volume – usually using regression analysis technique; and
3. Choosing the best model and verifying the accuracy of the table constructed.

Thus, the study requires enumeration of sample trees at various heights and subsequently calculating its volume. For this study, all individual standing trees above 15 cm dbh were enumerated, using laser equipment capable of providing accurate measurements of diameters along 2-meter sections up the stems of trees (Nur Hajar et al. 2010). This approach is cheaper and easier and allows the collection of larger samples of trees for the development of more reliable volume functions. Diameter taken at the bottom part of the stem (D_l) and upper diameters (D_2, D_3, D_4… D_n) were taken along the stem at every 2 m intervals. The top diameter of the stem was taken at the crown point which is the first branch that forms the tree crown. Diameter at breast height also be measured and is based on the standard procedure for measuring dbh in the field (i.e., trees will be measured 0.3 m above the ground level for a tree without buttress or with buttress less than one meter. For trees with a buttress of more than one meter, the measurement is taken at 0.3 m above the buttress. Species names were identified. A sample location was randomly chosen in the second growth hill dipterocarp forest in Negeri Sembilan. Sample trees were measured and distributed as equally as practicable throughout all sample locations for the purpose of volume function construction.

The over bark volume of each section of standing trees were calculated using either Smalian's or Newton's formula. Smalian's formula, $VI = 0.00003927 (D_1^2 + D_2^2) \times L$, used for log sections with two diameter measurements whereas Newton's formula, $VI = 0.00001309 (D_1^2 + 4D_m^2 + D_2^2) \times L$, was used for log sections with three diameter measurements.

Where L is the length of the log section, D_1 is the diameter lower-point of the log section, D_m is the mid-point of the log section and D_2 is the diameter at the upper-point of the log section. For each tree, the volume of the individual section was then added to give a total tree over bark volume.

The method of least squares was used for the construction of volume functions. The individual total tree volume derived, were regressed with the function models (unweighted and weighted) using R Statistical Software. Six of the most used regression models were fitted to the raw data of all species, Dipterocarp and Non-Dipterocarp. Furnival's Index (Furnival 1961) was used in selecting the most suitable volume regression model, as compared to the use of usual statistics such as coefficient of determination (R^2), and adjusted R^2 (R^2 adj) and/or residual mean square error (RMSE). The function with the smallest Furnival's Index indicates the best-fitted model.

This paper, however, deals only with the development of volume functions for all species and major species groups, Dipterocarp and Non-Dipterocarp.

RESULTS AND DISCUSSION

A total of 2,415 sample trees were measured from second growth hill dipterocarp forests at Negeri Sembilan (Table 1). The number of samples for all trees, Dipterocarp and Non-Dipterocarp is sufficient to be used in developing the volume functions based on the prescriptions given by Awang Noor & Mohd Radhi Chu (2002).

Table 1 Distribution of sample trees by species group and diameter at breast height (dbh) class of second growth hill dipterocarp forest in Negeri Sembilan

Major Group	Dbh Class						Total
	15-29.9	30-44.9	45-59.9	60-74.9	75-89.9	90 ++	
Dipterocarp	**251**	**185**	**105**	**42**	**8**	**10**	**601**
Non-Meranti	62	47	24	8	1	1	143
Meranti	189	138	81	34	7	9	458
Non Dipterocarp	**955**	**539**	**219**	**81**	**14**	**6**	**1,814**
Heavy Hardwood	10	8	5	4	2	-	29
Light Hardwood	248	123	49	16	1	2	439
Medium Hardwood	96	55	17	9	2	2	181
Other species	293	146	57	18	1	1	516
Partially marketable	237	175	79	28	6	1	526
Pioneer	71	32	12	6	2	-	123
Total	**1,206**	**724**	**324**	**123**	**22**	**16**	**2,415**

Six of the most used regression models were tested. Results of the regression analysis and the developed model for all species, dipterocarp and non-dipterocarp species group is presented in Table 2.

From Table 2, the volume functions for second growth hill dipterocarp forest in Negeri Sembilan are:

All species, $\mathbf{V/D^2 = 0.0016017 - 0.0548980(1/D) + 1.0184491\ (1/D^2)}$

Dipterocarp, $\mathbf{V/D^2 = 0.0011204 - 0.2255673\ (1/D^2)}$

Non-dipterocarp, $\mathbf{V/D^2 = 0.001026 - 0.1947\ (1/D^2)}$

The construction of local volume tables was based on volume functions developed for all species and major groups, dipterocarp, and non-dipterocarp. The main objective of constructing volume tables is to present expected volumes for trees of specified sizes in a second growth hill dipterocarp forest at Negeri Sembilan.

Table 2 The developed model for all species, dipterocarp, and non-dipterocarp species group

Volume function	Standard error	Geometric mean	Furnival's Index
ALL SPECIES			
$V = -2.865805 + 0.111973D$	1.3890	1.0	1.3550
$V = 0.2030587 - 0.0180767D + 0.0012345D^2$	1.3300	1.0	1.3550
$V = 0.2408 + 0.001069\ D^2$	1.3280	1.0	1.3980
$V/D = -7.26408 + 2.066661/D$	0.3397	2.2131	0.7518
$V/D^2 = 0.0016017 - 0.0548980(1/D) + 1.0184491\ (1/D^2)$	**0.0206**	**2451.11**	**8.4043^{-06}**
$v/D^2 = 0.001013 - 0.07244\ (1/D^2)$	0.0210	2451.11	8.5675^{-06}
DIPTEROCARP			
$V = -3.75660 + 0.13340D$	2.1900	1.0	1.3550
$V = 1.747283 - 0.084230D + 0.001889D^2$	2.1040	1.0	1.3550
$V = -0.4645369 + 0.0011773\ D^2$	2.0820	1.0	1.3980
$V/D = -7.4267 + 2.1188\ 1/D$	0.4006	3.2380	0.7518
$V/D^2 = 0.0014944 - 0.0400503\ (1/D) + 0.6766451\ (1/D^2)$	0.0262	3359.45	7.79893^{-06}
$V/D^2 = 0.0011204 - 0.2255673\ (1/D^2)$	**0.0258**	**3359.45**	**7.6798^{-06}**
NON-DIPTEROCARP			
$V = -2.369130 + 0.098990D$	1.0600	1.0	10.600
$V = 1.3247458 + 0.0525793D + 0.000477D^2$	1.0590	1.0	1.0590
$V = -0.1076 + 0.00009931D^2$	1.0610	1.0	1.0610
$V/D = -7.92732 + 2.23002\ 1/D$	0.2924	1.9397	0.0055
$V/D^2 = 0.0008554 + 0.0156905(1/d) - 0.5179762\ (1/D^2)$	0.0184	2216.25	8.3005^{-06}
$V/D^2 = 0.001026 - 0.1947\ (1/D^2)$	**0.0183**	**2216.72**	**8.2554^{-06}**

CONCLUSION

The volume functions for all species, Dipterocarp and Non-Dipterocarp groups were developed for second growth hill dipterocarp forest in Negeri Sembilan. Nevertheless, further verification should be conducted for the functions to be used at the operational level. The applicability test of these functions is necessary if they are to be used and applied elsewhere, i.e., outside the range of data and/or under other conditions.

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A NEW SILVICULTURAL APPROACH TO THE MANAGEMENT OF UNEVEN-AGED OF PENINSULAR MALAYSIA

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Being a major global supplier of hardwood products, the forests are expected to continue providing raw materials as required for timber industries. Much of these come from the natural production forests which are currently being managed through a silvicultural system called the Selective Management System (SMS). Such a system based on cutting regimes is being practised in many tropical countries as it is a practical system that is relatively easy to implement in the field and that could ensure the retention of trees to naturally regenerate into the next crop. However, over the years, it has been found that silvicultural systems based on cutting limits have resulted in residual forests that are less productive and diverse. This situation led to dispute among stakeholders concerning on production forests within Peninsular Malaysia to sustain timber resources for future generations. Thus, efforts are being undertaken to improve the current selective management system through improved silviculture. This paper presents a Silviculture Tree Selection System (STSS), in which some improvements have been put in place, including the selection of trees to be felled based on tree location, size, species, stem quality and commercial value. The study was conducted at the operational level with an area of 35 hectares located in Tekam Forest Reserve, Jerantut, Pahang. A 100 % pre-felling inventory for all individual trees with a size of 30 cm diameter at breast height and above has been undertaken to assess the existing growing stock. These individual trees were tagged, identified, and measured. Meanwhile, the location of all tagged trees has also been taken for mapping purposes. Trees to be felled were selected based on the tree location, size, species, stem quality, and its commercial value. The information generated from this project will be essential for improving the planning and management of the resource with the aim of enhancing future productivity.

Keywords: Silviculture tree selection system, sustainable forest management

INTRODUCTION

Selective logging systems are an important silvicultural intervention in the selective management system. If undertaken properly it produces disturbances similar to natural gaps (Webb 1997) albeit in an accelerated form. It does not necessarily result in significant changes to forest structure but stimulates natural regeneration and growth due to the formation of gaps which increases light conditions and space (Mathews 1989). Since its introduction in 1978, many of the stands that were managed under the SMS are now ready to be logged for the second time. There are concerns if the second rotation forests managed under the SMS are turning out to be what it was designed for.

According to Appanah and Weinland (1990), the SMS is a variant of the selective felling system practised in Indonesia and the Philippines. Much controversy prevails over its capacity to manage the dipterocarps forest on a sustainable basis. Appanah (2000) also indicated that a critical look at the SMS may reveal some shortcomings. Among the issues with regards to the management of forest on a sustainable basis include high removal of trees from the stand, high logging damage, large canopy gaps after harvesting, changes in structure and species composition and slow recovery. The research conducted involves the development and testing of new management prescriptions, Silviculture Tree Selection System (STSS) at the operational level to maintain species composition and ensures the retention of residual stand that is productive and able to sustain a healthy future crop.

MATERIALS AND METHODS

Pahang State Forestry Department had allocated an area of 35.0 hectares in Compartment 116B of Tekam Forest Reserve in the forest district of Jerantut, Pahang.

A baseline and inventory line had been prepared before the pre felling inventory. Pre-felling inventory was conducted which required a complete (100%) enumeration and mapping of all large trees ($\geq$ 30 cm diameter at breast height, dbh). The following parameters were measured:

1) Tree diameters were measured at approximately 1.3 m from ground level using diameter tapes,
2) Location (x and y coordinates) of trees were measured using laser range finder equipment,
3) Tree species were identified up to species level, and
4) Stem quality was determined qualitatively.

A cutting limit approach for the selection of trees to be felled as prescribed under SMS was not adopted. Here, the design for a selection of trees for harvesting requires information on the spatial distribution of commercial timber trees as well as trees to be retained. The 100% inventory data and tree location information were used to create a GIS database and a tree location map.

Trees to be felled are spatially distributed by creating a circular buffer around each tree as follows:

(a) 10 m radius buffer for trees 30−45 cm dbh
(b) 12 m radius buffer for trees 46−60 cm dbh
(c) 15 m radius buffer for trees > 61 cm dbh

The protocol for the selection of trees to be felled was based on the species, size, location, and commercial value of all trees with a diameter of 30 cm and above. The selection of trees to be felled was undertaken using software called 'STSS'. The selection process examined trees in the following batches:

Sequence	Criteria
Class 1	All trees with dbh > 75 cm and log quality 1
Class 2	All trees with dbh > 60 to 74.9 cm and log quality 1
Class 3	All trees with dbh > 75 cm and log quality 2
Class 4	All trees with dbh > 60 to 74.9 cm and log quality 2
Class 5	All trees with dbh > 45 to 59.9 cm, commercial value >RM800 and log quality 1
Class 6	All trees with dbh > 45 to 59.9 cm, commercial value <RM800 and log quality 1
Class 7	All trees with dbh > 45 to 59.9 cm, commercial value > RM800 and log quality 2
Class 8	All trees with dbh > 45 to 59.9 cm, commercial value < RM800 and log quality 2
Class 9	All trees with dbh < 45 and log quality 1

RESULTS AND DISCUSSION

Tree Stocking and Composition

A total of 2,501 trees with a diameter of 30 cm and above were enumerated in Compartment 116B, Tekam Forest Reserve, Jerantut, Pahang (Table 1). The percentage of dipterocarps in the stand in terms of tree density was about 18% and in terms of volume was about 29%. Table 2 indicates the ten most dominant species for all trees with dbh of 30 cm and above. *Syzgium* sp. is the most dominant species in Compartment 116 B, Tekam Forest Reserve (TFR).

Table 1 Stocking of trees (dbh > 30 cm) per hectare by diameter classes

Species group/ Diameter Class	30-44.9	45-59.9	60-74.9	75-89.9	90++	Total
No of individuals (no/ha)	33	23	11	3	1	71
Dipterocarp	4	4	3	1	1	13
Non-dipterocarp	29	19	8	2	1	59
Volume (m^3/ha)	19.54	31.31	28.11	14.02	8.89	101.87
Dipterocarp	2.83	7.07	9.07	5.85	4.46	29.27
Non-dipterocarp	16.71	24.24	19.03	8.17	4.43	72.60

Table 2 Ten most dominant species in terms of tree density in Compartment 116B, TFR

Species	Diameter class					Total
	30-44.9	45-59.9	60-74.9	75-89.9	90++	
Syzygium sp.	195	100	40	9		344
Elateriospermum tapos	53	62	34	1		150
Litsea sp.	95	24	18	6		143
Canarium grandifolium	55	55	23	7	1	141
Macaranga hosei	80	28	10	1		119
Dipterocarpus sp.	37	40	35	4	2	118
Sapium baccatum	41	44	16	5	1	107
Neoscortechinia kingii	50	41	8	1	1	101
Shorea parvifolia	29	34	19	11	5	98
Madhuca curtisii	36	31	14	6	2	89

Tree Distribution Map

A tree location map was produced to show the distribution of all sampled trees within the study area. It could be seen that the trees when viewed as a large group were generally well distributed (Figure 1).

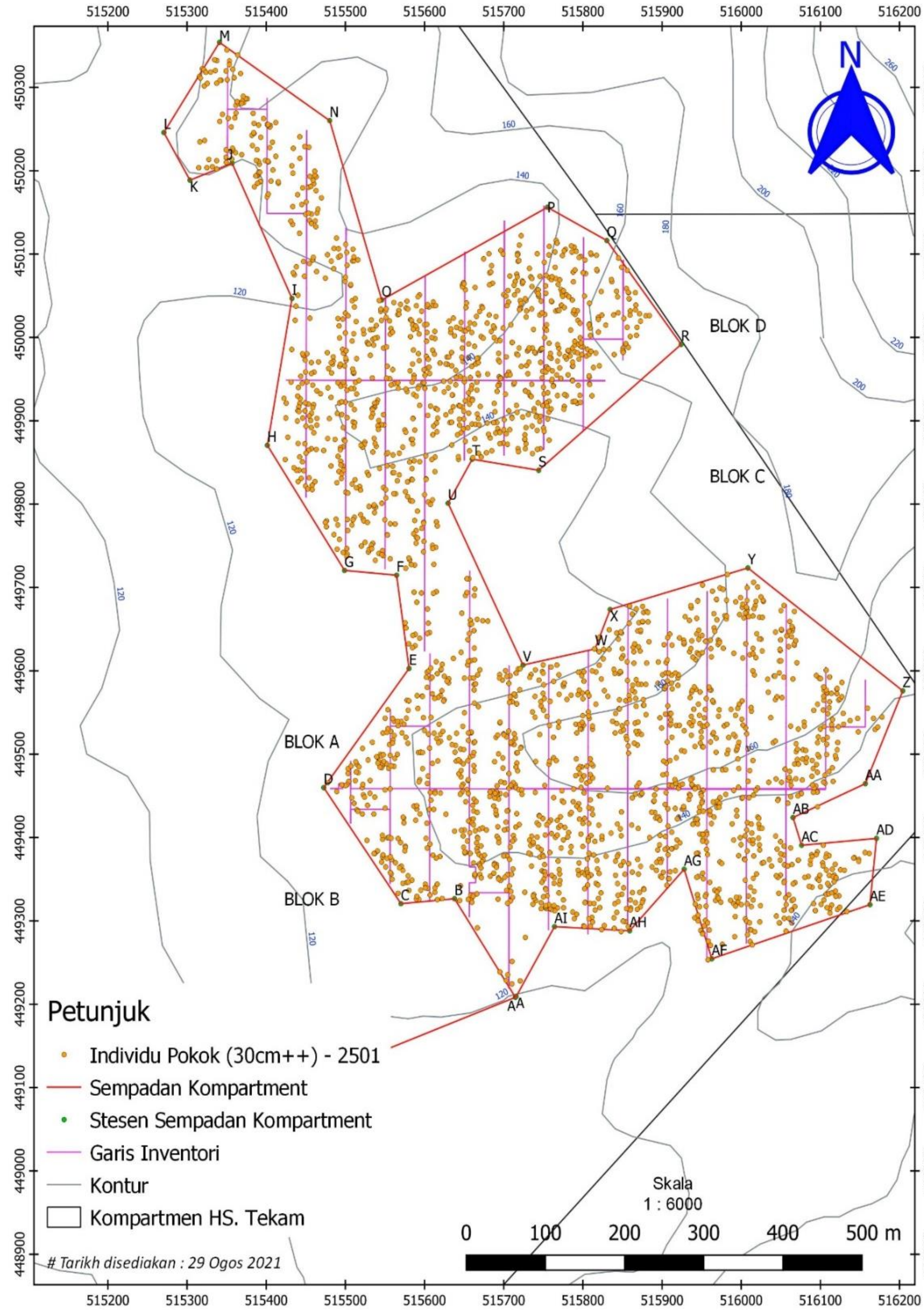

Figure 1 Tree location map for all individual trees > 30 cm dbh in Compartment 116B, TFR, Jerantut, Pahang

Tree Selected for Felling

For each selection process, a group of trees was selected for felling where a clear buffer was created between the selected trees. The selection process proceeded sequentially to the next batch of trees, and then the subsequent batches until all trees had been examined and considered in the selection process, and there is no more space within the site to fit any additional trees for felling. The final selection of trees is shown in Figure 2. For each batch of the selection process, there was a large portion of trees within the batch that were retained. As the batches constitute trees of a particular diameter class, the selection process will ensure that forest structure and species composition are maintained.

After the completion of the selection process, a total of 299 trees or about nine trees per hectare were selected consisting of 104 dipterocarps and 195 non-dipterocarps. The total volume selected for felling was 819.20 m^3 or 23.41 m^3 ha^{-1} (Table 3). The results indicated that there were still a large number of trees retained amounting to 63 trees ha-1 (Table 4) and the distribution of trees to be retained is in Figure 3.

Table 3 Total stocking of trees that were selected for felling in Compartment 116B, TFR

	Diameter class, cm					Total
	30-44.9	**45-59.9**	**60-74.9**	**75-89.9**	**90++**	
No of Individuals	79	54	97	47	22	299
Dipterocarp	19	10	41	19	15	104
Non-dipterocarp	60	44	56	28	7	195
Volume (m^3)	52.09	79.02	288.66	208.82	190.61	819.20
Dipterocarp	15.96	17.74	141.59	97.74	123.17	396.20
Non-dipterocarp	36.13	61.27	147.08	111.08	67.44	423.00
Commercial value (RM)	41,654.48	96,807.27	400,608.07	291,146.59	297,783.24	1,127,999.65
Dipterocarp	20,903.81	29,553.07	251,321.17	170,403.49	215,960.32	688,141.86
Non-dipterocarp	20,750.68	67,254.19	149,286.91	120,743.10	81,822.91	439,857.79

Table 4 Stocking of trees to be retained per hectare in Compartment 116B, TFR

	Diameter class, cm					Total
	30-44.9	**45-59.9**	**60-74.9**	**75-89.9**	**90++**	
No of Individuals (No/ha)	31	21	9	2	0	63
Dipterocarp	3	4	2	1	0	10
Non-dipterocarp	27	18	7	1	0	53
Volume (m^3/ha)	18.05	29.06	20.88	7.03	3.44	78.46
Dipterocarp	2.37	6.56	5.68	2.40	0.94	17.95
Non-dipterocarp	15.68	22.49	15.20	4.63	2.51	60.51

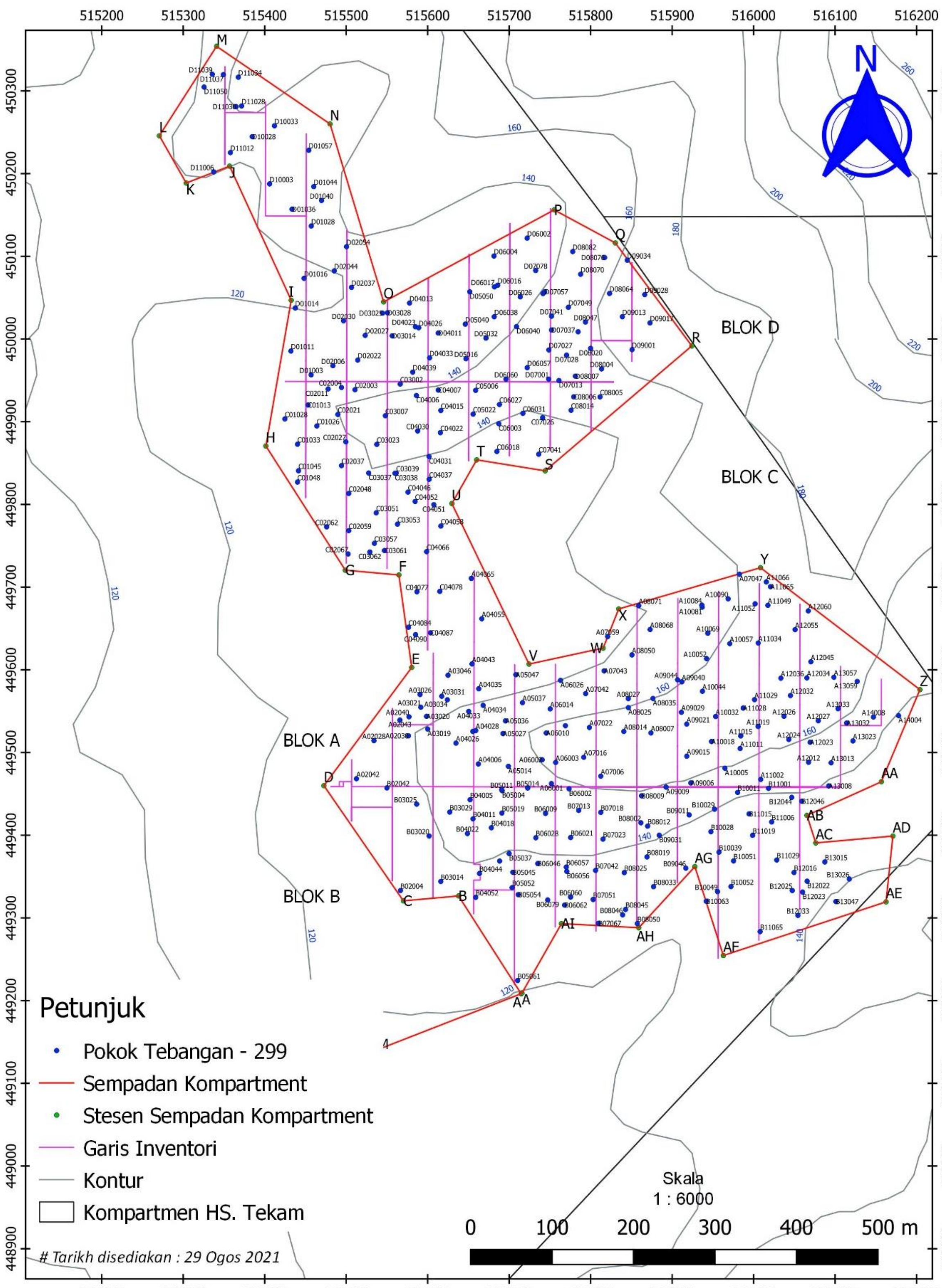

Figure 2 Location of all trees selected for felling in Compartment 116B, TFR, Jerantut, Pahang

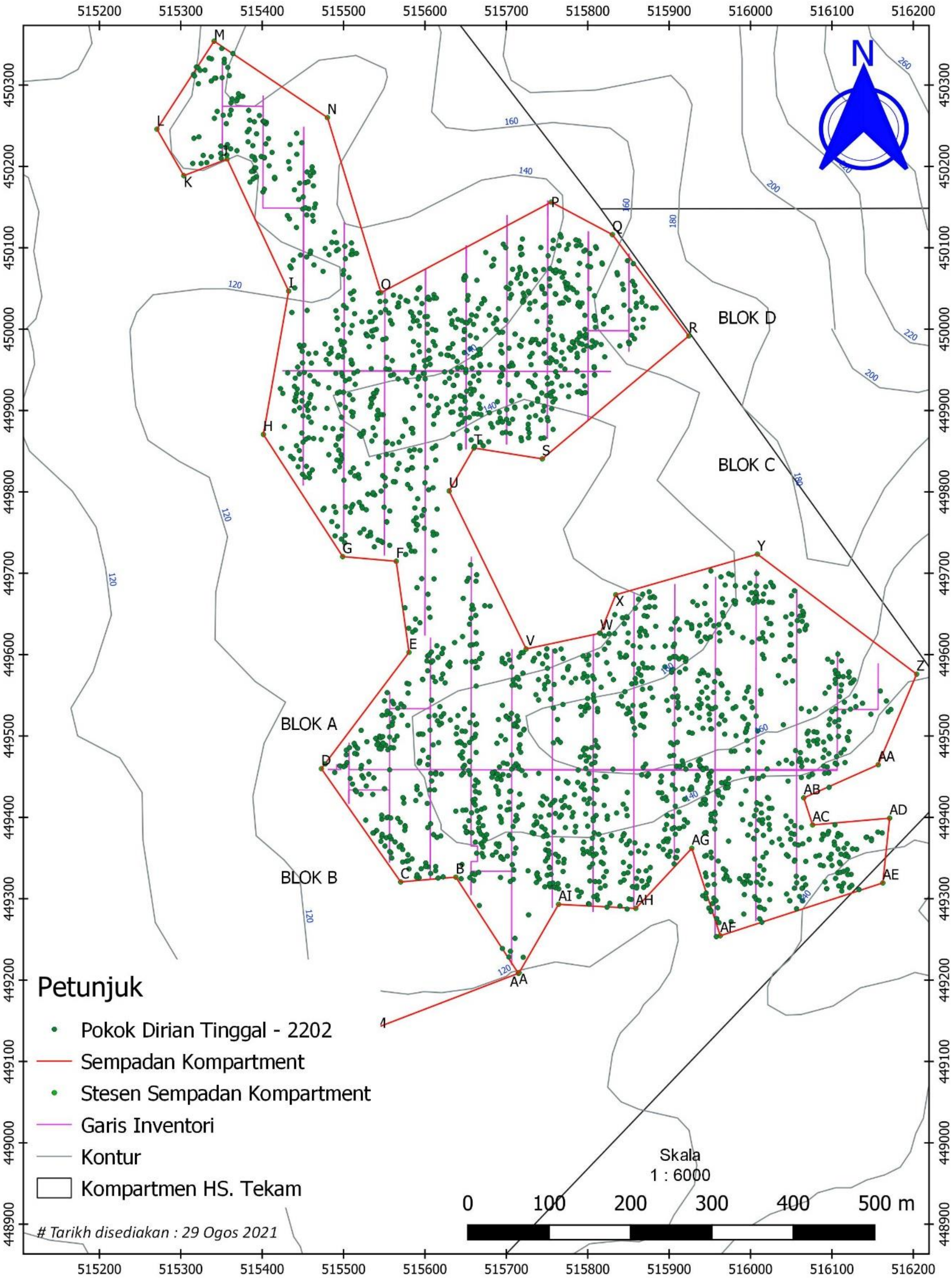

Figure 3 Distribution of trees to be retained in Compartment 116B, TFR, Jerantut, Pahang

CONCLUSION

Under the new management regime, complete and comprehensive information of all large trees which includes the locations, size and other attributes data were collected to allow forest managers to design the residual stand appropriately. The information is utilised optimally to ensure that the selected trees for felling would result in minimum damage to the residual stands and sufficient residuals would remain to make a healthy residual stand. The establishment of a 10 to 15 m radius buffer ensured that trees selected for felling would be at least 30 m apart and proportionally dispersed within the concession. With fewer trees removed and well-spaced apart coupled with directional felling, the new management prescription could be able to mimic the single tree fall gaps that normally occur in the undisturbed forest dynamics (Webb 1997; Sist et al. 2003a).

The selection of trees under this protocol was made possible with the development of 'STSS software. The application of the protocol proved to be effective as it resulted in about 9 trees ha^{-1} with a volume of 23.41 m^3 ha^{-1} being selected for felling. The selected trees were also evenly spaced out throughout the site to ensure a better growth environment for the residual stand. This amount seems to be in line with most RIL recommendations where the number of trees removed should be around 8 to 12 trees ha-1 (Richard 2000; Pinnard et al. 2000; Sist et al. 2003b). The suggested approach would ensure that the integrity of the residual forest stands is not compromised to an extent that will affect its capacity to regenerate to the desired crop within the cutting cycle.

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DISTRIBUTION AND STATUS OF *MELALEUCA* FOREST IN PENINSULAR MALAYSIA

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Melaleuca forest is one of the forest types that can be found in Malaysia. However, unlike any other forest type in this country, only a few studies have been carried out on this forest. The majority of studies have focused on Terengganu since this state has the largest melaleuca forest in Malaysia. Thus, a study is needed to acquire current information on the distribution and status of melaleuca forest in Peninsular Malaysia. Mapping the distribution of *Melaleuca* forest for Peninsular Malaysia was done using Landsat-8 and Sentinel-2 satellites data. Basic stand information of *Melaleuca* forest was also acquired based on field inventory data. In 2020, the total area of *Melaleuca* forest in Peninsular Malaysia is estimated at around 22,879 hectares or 0.4% of the total forested area in Peninsular Malaysia. This forest can be found only in Terengganu, Kelantan, Melaka, Selangor, Johor and Negeri Sembilan. A total of 13 clusters of field inventory have been established and the average stand density, basal area, and above-ground carbon of this forest are 1,279.24 tree ha^{-1}, 29.48 m^2 ha^{-1}, and 116.80 tonne C ha^{-1}.

Keywords: *Melaleuca* forest, mapping, Landsat-8, Sentinel-2, Peninsular Malaysia

INTRODUCTION

The *Melaleuca* forest, known locally as the "Gelam" forest, is one of the freshwater marsh forests. The name comes from the tree species *Melaleuca cajuputi*, as the forest consists almost entirely of this tree species. *M. cajuputi* is a native plant of the *Myrtaceae* family and the genus *Melaleuca*. There are several species of this genus, but *M. cajuputi* is common in Malaysia. Colloquial names used for this species are Cajaput, Cajaput-tree, Cajeput, Gelam Bark, Paper Bark Tree, White-wood (English), Gelam, Kayu Puteh, Kayu Putih, and Gelam Tikus (Malay) (MyBIS 2021). Melaleuca forests are native to Southeast Asia, New Guinea, and Australia, and are not found elsewhere in the world (Tran 2015). It is reported that the extent of this forest on the Malaysian Peninsula in 1997 was at least 41,520 ha, with Terengganu having the largest range.

Some studies have been carried out in the *Melaleuca* forest in Malaysia related to habitat, ecology, biophysical and biochemical characteristics of *M. cajuputi* species (Masitah et al. 2015; Kasawani & Kamaruzaman 2009; Jamilah et al. 2014; Jamilah et al. 2017). However, only a few studies have been conducted on mapping the distribution of this forest. One of the reasons is that this forest is considered abandoned and has less commercial value than any other forest types in this country such as inland, peat swamp, and mangrove forests. Most of the studies that utilise remote sensing technology are focusing on the technique to identify *Melaleuca* forest and focus on Terengganu only

(Saberioon et al. 2010; Noor Afira 2007; Kasawani & Kamaruzaman 2009). Thus, the distribution and status of this forest for Peninsular Malaysia are unknown. Given these limitations, this study was conducted to acquire up-to-date information on this forest for Peninsular Malaysia and make the data available for future studies and management related to this forest. This study not only focuses on mapping the distribution of *Melaleuca* forest but also acquiring basic information of forest stands of this forest.

MATERIALS AND METHODS

The Sentinel-2 and Landsat-8 Operational Land Imager (OLI) satellite images were used as the primary input to identify and classify the *Melaleuca* forest in Peninsular Malaysia. Ground truth data was also used to support the identification of the forest on the satellite images, as well as to assess the accuracy of the classification products. Aside from ground truth, field inventory activities were also carried out to acquire basic forest stands information.

Satellite images from two satellites, which are Sentinel-2 and Landsat-8, were acquired within the years 2019 and 2020 to identify and map the distribution of *Melaleuca* forest for Peninsular Malaysia. Mapping using satellite images nowadays is the most widely used approach since it can cover a big area, is cost-effective, and does not take a long time to complete. Furthermore, each satellite images have their own spatial and spectral characteristics that allow the users to select the best satellite images to fit their purposes. Users can also make use of several spectral bands of one image for better viewing of the area (Figure 1) and maximize the accuracy of the classification when doing the mapping.

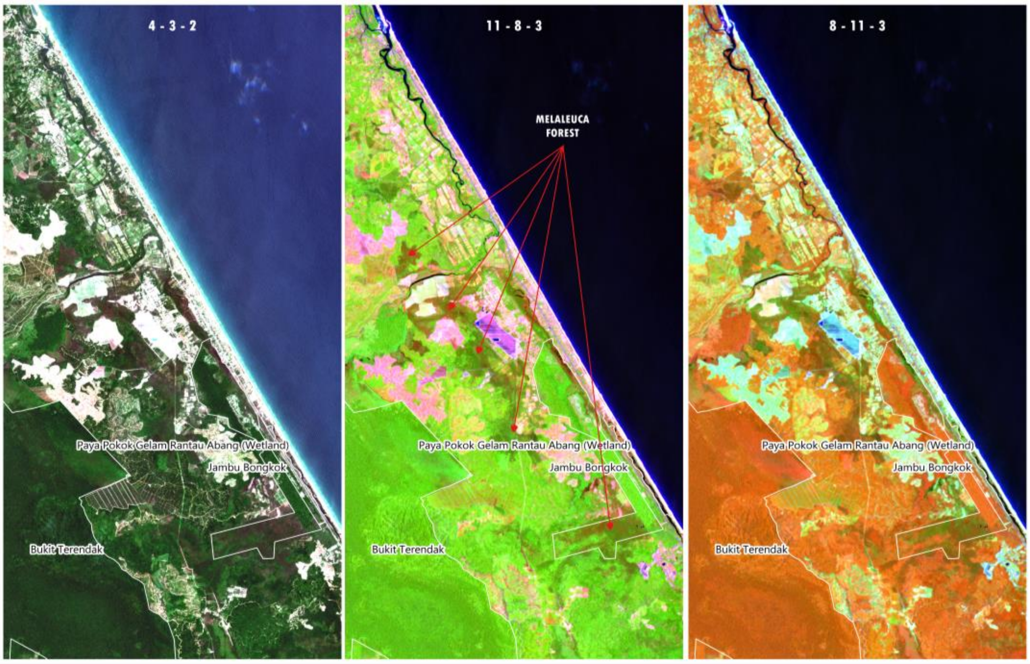

Figure 1 Sentinel-2 images with different colour combinations for the identification of *Melaleuca* forest

Sentinel-2 and Landsat-8 images are some of the most common remote sensing data because these data are freely available to any user. Sentinel-2 images were downloaded from https://scihub.copernicus.eu/dhus/ and Landsat-8 images were downloaded from https://earthexplorer.usgs.gov/. For some of the areas that cover by clouds, the same scene from different dates was acquired. Image processing processes were applied to each image to improve the quality of the image. Those processes include conversion of digital number (DN) to top-of-atmospheric (TOA) reflectance, cloud masking, and geometric correction.

A classification process was done on all the images to classify *Melaleuca* forest and other land uses. Support vector machine (SVM) was used for the classification. Some improvements were made to the results of the classification to improve the classification accuracy. Some areas that were misclassified were removed and the boundary of *Melaleuca* forests was edited and improved. The ground truth data collected in this study is also used as a reference to improve the classification results and to assess the classification accuracy. Finally, a distribution map of the *Melaleuca* forest for Peninsular Malaysia was produced. Some analyses were made based on the final result and those analyses are calculating the extent of *Melaleuca* forest by state and their status.

Field inventory was also carried out in this study to acquire some basic forest stand information. The selection of location for field inventory activity is based on the distribution of *Melaleuca* forest that had been produced from the classification process. The inventory plot design that was originally designed for mangrove forests was used to collect the data (Kauffman & Donato 2012) as shown in Figure 2. One cluster consists of 6 plots and the radius of each plot is 7 m. The distance from one plot to another is 25 m. All trees that have a minimum diameter at breast height (DBH) of 5 cm were measured and recorded and the species of each tree is also recorded. All field data were stored in one database for ease of management. All the data were analyzed using R software (R 2013) to get some of the basic parameters of the forest such as stand density, basal area, biomass, and percentage of *Melaleuca* tree.

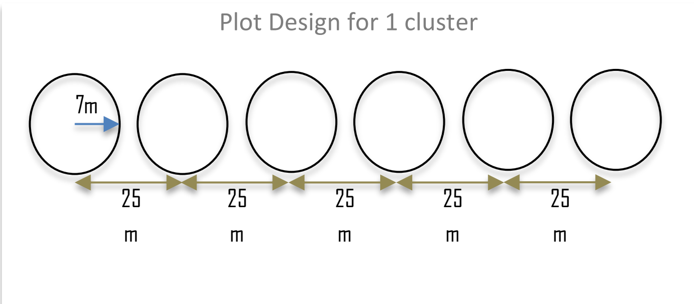

Figure 2 Plot design that was used to collect field data

RESULTS AND DISCUSSION

The extent of the *Melaleuca* forest in Peninsular Malaysia is estimated at around 22,879 hectares. Based on this size, this forest only consists of 0.4% of the total forested area in Peninsular Malaysia. The distribution of this forest is shown in Figure 3.

Figure 3 Distribution of *Melaleuca* forest in Peninsular Malaysia based on classification of Sentinel-2 and Landsat-8 images

The result showed that Terengganu, Kelantan, Selangor, Negeri Sembilan, Melaka, and Johor are the only six (6) states that have this forest. Terengganu has the largest extent of this forest with an area of 14,748.72 hectares as shown in Table 1. It contributes 64.5% of the total *Melaleuca* forest in Peninsular Malaysia. Kelantan has the second-largest Melaleuca forest after Terengganu with an area of 6,530.31 hectares (27.8%). Melaka, Selangor, Johor, and Negeri Sembilan only contribute a small portion of the total *Melaleuca* forest in Peninsular Malaysia with only 7.7% of the total area. In terms of the status of this forest, most of the area is on private land and state land area, only Terengganu has this forest in the forest reserve area. Jambu Bongkok Forest Reserve located in Dungun, Terengganu is a well-known forest reserve that conserves Melaleuca forest in this country.

A total of 13 clusters with 78 plots have successfully been established in this study. Figure 4 shows the size of all trees measured for each cluster. In general, the variations in terms of the size of the tree are small compared with inland and peat swamp forests. The stand density of each cluster also varies. Not all area that is dominated by smaller trees will have high stand density like cluster 6 and 7. Clusters 1 and 9 that are dominated by smaller trees have low stand density. Another thing that can be observed from Figure 4 is the size of the *Melaleuca* tree. Not many *Melaleuca* trees can reach a dbh of more than 40 cm. Based on 13 clusters, the stand density, basal area, and above-ground carbon of *Melaleuca* forest are 1,729.24 trees ha^{-1}, 29.48 m^2 ha^{-1}, and 116.8 tonne C ha^{-1}.

Table 1 The extent of *Melaleuca* forest by states and their status

No	State	Area (ha)	Pct (%)	Comparison with FRIM area (X)	TPA	Others
1	Terengganu	14,748.72	64.5	27.1	375.94	14,372.78
2	Kelantan	6,530.31	27.8	12.0	-	6,530.31
3	Melaka	626.47	2.7	1.2	-	626.47
4	Selangor	521.04	2.3	0.9	-	521.04
5	Johor	415.22	1.7	0.8	-	415.22
6	Negeri Sembilan	217.57	1.0	0.4	-	217.57

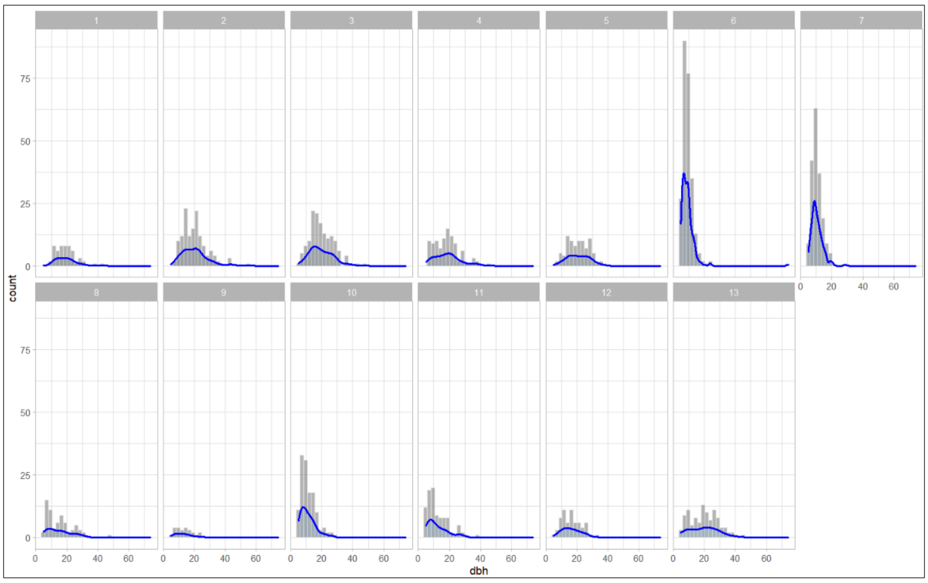

Figure 4 A histogram that shows the size of trees in each cluster

CONCLUSION

This study has successfully mapped the distribution of *Melaleuca* forest in Peninsular Malaysia by using Sentinel-2 and Landsat-8 images. The study has estimated the extent of this forest about 22,879 hectares with Terengganu has the largest extent followed by Kelantan, Melaka, Selangor, Johor, and Negeri Sembilan. Basic forest stand information has also successfully been done with the average stand density, basal area and above-ground carbon are about 1,729.24 trees ha^{-1}, 29.48 m^2 ha^{-1}, and 116.8 tonne C ha^{-1}.

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MALAYSIA WETLAND DIRECTORY

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A wetland is an area of land that is either covered by water or saturated with water or from wherever water meets land. Wetlands have a high biological diversity and play a vital role in supplying ecosystem services such as food supplies, water supply, seizure protection, flood control, erosion management, water filters, and local weather stabilizer. Recognizing the importance of wetlands, Malaysia has a clear policy to protect and conserve their value. Malaysia has taken the necessary precautions, including signing up to the Ramsar Convention on March 10, 1995. The Ramsar Convention is an international wetlands agreement that establishes a framework for international collaboration in wetland habitat conservation activities. The Malaysian Wetland Directory, published in 1987, was the first published in recognizing the country's wetlands of interest. A new and updated version of the wetland directory is necessary as there have been changes in the physical condition of the wetland areas which no longer reflect the current situation. This directory played an important role in creating awareness on the importance of wetlands not only for their intrinsic value to nature conservation, but also for the part that wetlands play as breeding grounds of commercial fresh and saltwater species of fish and crustaceans.

Keywords: Wetlands, wetland directory, Ramsar policy, biological diversity

INTRODUCTION

Wetlands are areas of land that are permanently or periodically flooded or inundated by water. Wetlands also are defined in Article 1.1 of the Ramsar Convention as areas of marsh, fen, or peatland of water, whether natural or manmade, permanent or temporary, with water that is static or flowing, fresh, brackish, or salt, including regions of sea water with a depth of no more than six meters at low tide (Ministry of Natural Resources and Environment (NRE) 2011). A wetland is also a land area that is saturated with water permanently or seasonally and characterized by shallow water overlying waterlogged soil and interspersed submerged or emergent vegetation and one of the world's third most important ecosystems. The global wetland size ranges from 5.3 to 12.8 million km^2 and it is estimated that almost 86% of the total world's wetland areas are found in tropical, subtropical, and boreal regions, while the remaining 14% are found in temperate zones (Rajpar & Zakaria 2014). Wetlands are widely acknowledged to have a vital role in preserving biological diversity value. It is yet another tropical ecosystem with scientific characteristics that fulfil critical ecological functions. Wetlands contribute significantly to serve essential services such as water filtration, nutrient retention, water table management, shoreline and storm protection, climate change mitigation, flood mitigation, erosion control, groundwater replenishment, and habitats for biodiversity. All these services are critical for maintaining Malaysia's unique natural resources and terrain.

Malaysia has an extensive area of natural and man-made wetlands. Geographically, natural wetlands cover areas of peat swamp, mangroves, rivers, lakes, and coral reefs, and they are a habitat for flora and fauna. Meanwhile, there are also man-made wetlands such as lakes and paddy fields. Overall, there are 31 types of wetlands in Malaysia: natural and man-made wetlands. Nonetheless, some of the wetlands are small by land area and not covered in this directory (Ismail et al. 2021). Based on the information and data availability, there are 16 major types of wetlands that have been selected including 12 natural wetlands (mangroves, peat swamp, *nipa* swamp, *melaleuca* swamp, marshes, mudflats, sandy beaches, rocky shores, coral reefs, seagrass bed, river systems and natural lake systems including oxbow lakes), and four (4) man-made wetlands (reservoir or dam, paddy field, aquaculture as well as created and rehabilitated wetlands).

Mangroves, river systems, tropical peat swamp forests, and nipa swamps constitute the main wetlands ecosystem can be found in Malaysia which is located along the coastline. According to Zainuddin (2008) there are about 629,038 ha of mangrove area in Malaysia, mostly found in Sabah (60%) and about 22% of it in Sarawak. Intertidal mud and sand flats are extremely important wetland habitats in Malaysia. They fringe the majority of Malaysia’s coastlines, and in certain places can be several kilometres wide at low tide. Mudflats that are associated with major mangrove forests are essential for important bird areas (IBA) (Table 1) which are rich in benthic fauna and represent the richest feeding grounds for migratory shorebirds and resident water birds such as herons, egrets, and storks.

The previous Malaysian Wetlands Directory by Malaysia Conservation Foundation (1987) needs to be reviewed as the information in the directory are over 35 years old and there have been changes in the physical condition of the study area which no longer reflect the current situation and needs to be updated.

MATERIALS AND METHODS

This directory employs a number of desktop data collection and ground truthing methods. All the information collecting will be processed and verified by using the Global Positioning System (GPS) equipment and Geographic Information System (ArcGIS) software for examination of any geometric and radiometric adjustments. Then, other related data will be collected from the state forestry department, land and district office and related agencies for confirmation. Desktop data collection includes information on research that has been conducted in the wetland area for reference and guidance. Each site’s information was updated and verified to reflect the current situation of the area. A guideline proposed by National Ramsar Information Toolkit was used, in accordance with the Ramsar Convention Criteria for selection of demonstration sites based on the wetlands criteria, indicators, data, and information. This directory will be reviewed and verified by the related departments or agencies prior to publication.

Table 1 Summary of Important Bird Areas that qualify as Ramsar sites in Malaysia [taken from Birdlife International (2005)]

IBA CODE	IBA NAME	AREA (HA)	RAMSAR SITE NAME	AREA (HA)
PENINSULAR MALAYSIA				
MY 15	SOUTH WEST JOHOR COAST	8,650	TANJUNG PIAI	526
			PULAU KUKUP	647
MY 03	TELUK AIR TAWAR-KUALA MUDA COAST	7,200		
MY05	MATANG COAST	43,502		
MY11	NORTH-CENTRAL SELANGOR COAST	28,000		
MY18	SOUTH-EAST PAHANG PEATSWAMP FOREST	325,000		
SABAH				
MY19	PULAU LAYANG-LAYANG	20		
MY23	KINABATANGAN FLOODPLAIN	100,000		
MY28	KLIAS PENINSULA	180,000		
MY30	KULAMBA WILDLIFE RESERVE	20,682		
MY32	MANTANANI ISLANDS	61		
MY33	TEMPASUK PLAIN	40,000		
SARAWAK				
MY 34	TANJUNG DATU-SAMUNSAM PROTECTED AREA	24,177		
MY 36	TALANG-SATANG NATIONAL PARK	19,414		
MY37	BAKO-BUNTAL BAY	3,590		
MY41	SADONG-SARIBAS COAST	60,000		
MY42	PULAU BRUIT	1,776		
MY52	LOAGAN BUNUT NASIONAL PARK	10,736		
MY55	BRUNEI BAY	19,500		

RESULTS AND DISCUSSION

Malaysia is blessed with 5.2 million ha of wetland resources which cover 15.76% of the total land area of the country. Most of these wetlands are divided into mangroves (11.6%), peat swamp (29.67%), freshwater swamp (1.09%), *Melaleuca* swamp (0.44%), lakes (0.95%), and paddy fields (0.75%). This indicates that wetlands are an integral part of Malaysia's various landscapes and biodiversity and play a significant role in maintaining the flora and fauna across the country. The wetland ecosystem provides diverse tangible and intangible benefits on a sustainable basis. The wetlands are a source of many valuable ecological resources such as water supply, food, flood control, and recreation to humans. They also provide biological diversity and countless fauna such as birds, fish, amphibians, reptiles, mammals, and aquatic invertebrates (Rajpar & Zakaria 2014).

The extensive extent of natural wetlands in Malaysia is shown in Table 2. The main wetlands ecosystem located in Malaysia is found near the coastline and comprises of mangroves, river systems, tropical peat swamp forests, nipa swamps, and freshwater swamp.

Table 2 Estimated total natural wetland areas in Malaysia by state and wetland type (excluding sandy beaches, rocky shores, coral reefs, seagrass bed, river systems and natural lake systems)

State/Wetland Types	Mangroves	Mudflats	Freshwater Swamp	Peat Swamp Forest	Marshes	Nipa Swamp	*Melaleuca* Swamp	Total (ha)
Peninsular Malaysia	110,952	53,951	355,190	302,000	33,937	25,120	22,877	**939,072**
Sabah	378,195	n.a	152,702	120,000	721,216	758,770	n.a	**2,075,883**
Sarawak	139,890	n.a	28,907	1,120,000	n.a	869,700	n.a	**2,178,497**
Total	**629,037**	**53,951**	**536,799**	**1,542,000**	**755,153**	**1,653,590**	**22,877**	**5,196,407**

Note: n.a = data not available

The Malaysian Wetland Directory also include the 114 important wetland sites as listed in Appendix 1, of which 65 are in Peninsular Malaysia and 49 in East Malaysia. Information collected for each site include location, description of the site, climatic conditions, principal vegetation, land tenure, conservation measure taken, conservation measure proposed, land use, possible changes in land use, disturbance, and threats as well as conservation value (economic value/ social, flora and fauna) (Table 3).

Verification and reviews on each of the sites found that the majority of the areas have undergone significant changes, and some were completely vanished due to land use change, mostly to agriculture and resident area. The affected areas can be found in Table 4. Generally, most of the freshwater swamp forests have been virtually disappeared due to conversion to agricultural and residential uses. Figures 1 and 2 show the different site maps in the book published in 1987 (a)(c) and the current updated version (b)(d). Several sites are facing forest degradation such as Tanjung Piai, Merbok Mangrove and Pulau Indah, while, some wetland area has extended, such as in Delta Kelantan and Pulau Kukup. Conversion of wetlands into agriculture, aquaculture ponds, industrial and urbanization, ship activities, and deforestation are among the critical challenges to wetlands. Another important factor is the severe coastal erosion, which may have been worsened by the loss of mangroves in several regions. Mangroves in Peninsular Malaysia, on the other hand, confront a variety of threats, including typhoons and high winds (Hamdan et al. 2012).

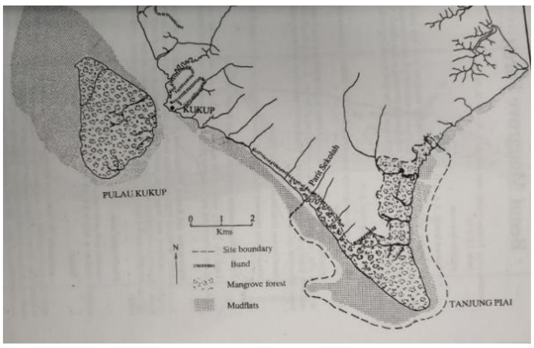
Table 3 Example of the information collected for each site

Sungai Golok *Melaleuca* Swamp	
TYPES	**DESCRIPTIONS**
Location	Along the southern side of Sungai Golok, near the border between Thailand (Narathiwat) and Kelantan (Kampung Bakong).
Latitude & Longitude	6°05'-08' N, 102°03'-05' E.
Area	Approximately 578.38 ha of *Melaleuca* forest.
Altitude	Sea level.
Wetland type	11, 15, 21.
Description of the site	The Golok River is a river that lies on the border between Malaysia and Thailand. It is spanned only by the Malaysian-Thai Friendship Bridge (Hussin, F., 2013). Narrow stretch of *Melaleuca* swamp forest along Sungai Golok. It is very patchy as much has been reclaimed for paddy fields, horticulture and rubber plantations. *Melaleuca* swamp is near to Kg. Bakong, Pasir Mas, Kelantan.
Principle vegetation	*Melaleuca cajeputi* and *Nypa fruitcans* along the river.
Land tenure	State Government of Kelantan and some of the area are private land
Conservation measures taken	None.
Conservation measures proposed	Proposed to be gazetted as Forest Reserve.
Land use	There are palm oil plantations, paddy fields, mixed horticulture, rubber plantations and settlements with commercial area and infrastructure near to the wetland region (Federal Department of Town and Country Planning, 2018).
Soil suitability class	Classes 3d(t) 2d
Climatic conditions	In 2017, the annual rainfall was about 3,800.6 mm with the highest rainfall of 1,024.6 mm (November) and the lowest rainfall of 11.7 mm (February). Average temperature is about 26.8°C and the highest air temperature was recorded in April, 27.3ºC, while, the lowest in January, 24.6ºC.
Possible changes in land use and proposed development projects	Further conversion to paddy fields, palm oil and other crops.
Conservation values:	
Economic and social values	Source of firewood and timber poles for the local population. Sg. Golok is one of the major economic centers in the southern part of Thailand, while close to the border is the Pengkalan Kubor Duty Free in Rantau Panjang, one of the economic centers in the State of Kelantan .
References	1. Federal Department of Town and Country Planning, 2018). 2. Hussin, F. (2013).

Table 4 Newly added, vanished, and renamed sites in the directory

Newly added sites	
Setiu Wetlands	
Kenyir Lake	
Ayer Hitam North Forest Reserve	
Paya Indah Wetland	
Klang Gate Water Catchment	
Batu Maung	
Langkawi Geopark	
Kuala Perlis Mangrove / Pulau Ketam Forest Reserve	
Vanished sites (due to land use change)	
Telok Swamp Forest	Development area
Melintang Swamp Forest	Agriculture area
Telok Intan Swamp Forest	Agriculture area
Renamed sites	
Previous name	Current name
Tumpat Lagoon	Kelantan Delta
Pulau Lumut	Pulau Indah
Kisap Mangrove Ayer Hangat Mangrove	Kilim mangroves
Banjar North Forest Reserve	Kuala Selangor Mangrove Forest 1: North Of Kuala Selangor
Banjar South Forest Reserve	Kuala Selangor Mangrove Forest 2: South Of Kuala Selangor
Likas Swamps	Kota Kinabalu Wetland
Lotung Lake	Linumunsut Lake
Third Division Swamp Forest	Mukah-Bintulu Division Swamp Forest

a



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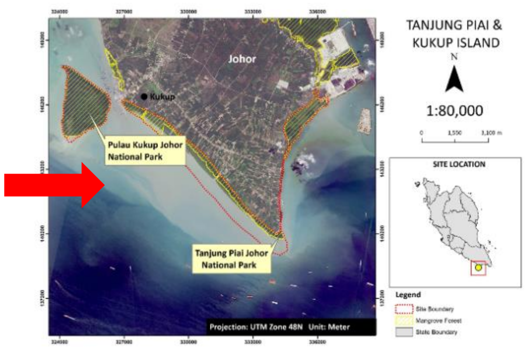

Figure 1 Example of the aerial map for Tanjung Piai & Pulau Kukup (a) 1987 and (b) current

c d

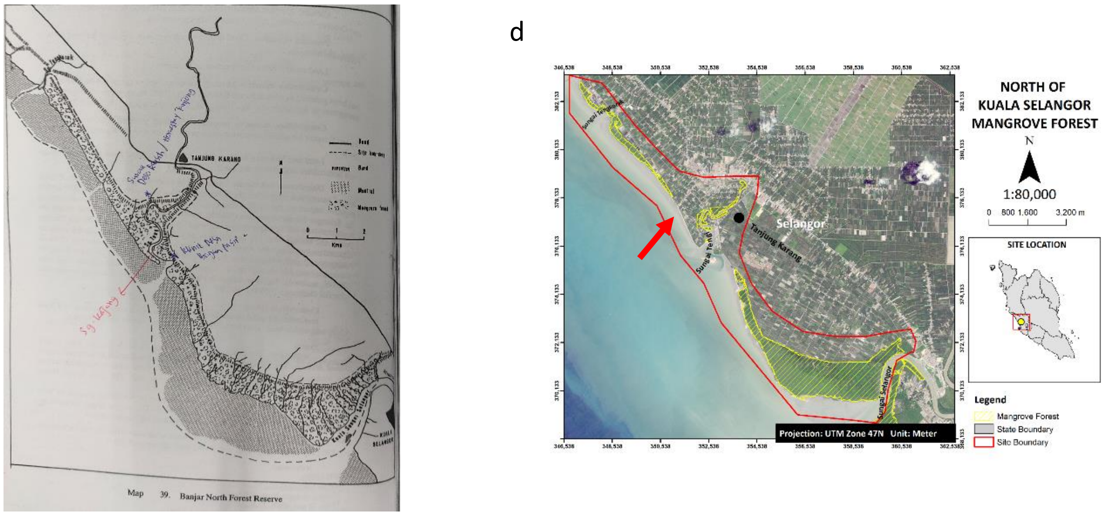

Figure 2 Example of the aerial map for North of Kuala Selangor Mangrove Forest (c) 1987 and (d) current [arrow shows degraded area]

Future preservation and protection of wetlands forest in Malaysia should be continued and integrated across all government agencies or non-governmental organizations (NGOs) to strengthen Malaysian wetland management. This may be accomplished by combining the most recent discoveries and updating knowledge through R&D. Currently, existing wetland areas must be maintained to guarantee that their ecological variety is preserved. Public awareness and education programs should be improved. This initiative will help to preserve our wetlands for the sake of future generations.

CONCLUSION

The publication of this directory is very timely, as there are growing awareness on the importance of wetlands and its ecosystem value. Nonetheless, wetland area degradation should be taken seriously as three important wetland areas have completely vanishes (Telok Swamp Forest, Melintang Swamp Forest, and Telok Intan Swamp Forest) to make way for agriculture and urban development. While other wetland areas were found to be decreasing in size due to development pressure and erosion. Thus, this directory would be useful to plan for development, policymakers, government agencies, and associated stakeholders in order to establish a better integrated wetland management, particularly to safeguard the wetlands.

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Appendix 1

Table of Content Malaysia Wetland Directory

NET ECOSYSTEM PRODUCTION (NEP) STUDY OF NATURAL FOREST IN PASOH FOREST RESERVE, NEGERI SEMBILAN, MALAYSIA

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Net ecosystem production (NEP) is a fundamental concept of ecosystems that refers to the difference between gross primary production and total ecosystem respiration. Defined this way, NEP represents the total amount of organic C available for storage within the system or loss from it. This study aimed to quantify net carbon accumulation of forest under the pristine condition in lowland dipterocarp forest in Malaysia and to estimate the metabolic status of terrestrial ecosystem whether it is a net autotrophic (production exceeds respiration) or net heterotrophic (respiration exceeds production). Total net primary productivity (NPP) estimated from this study was 7.30 Mg C ha^{-1} $year^{-1}$ while root respiration (R_s) referring to heterotrophic respiration was 7.52 Mg C ha^{-1} $year^{1}$. Hence, The NEP value was –0.22 Mg C/ha. NEP has a negative value when carbon loss exceeds carbon input in an old-growth forest with a mature stand between 2017 and 2018. For average soil CO_2 efflux ($\mu molm^2s^{-1}$), the results are as follow: 1.639 (morning) 1.955 (afternoon) and 2.732 (evening) and chamber CO_2 concentration is above 374 $\mu molmol^{-1}$ at 3 cm insertion soil collar depth. The average flux during daytime was 2.10 $\mu molm^{-2}$ s^{-1} which is typical in an inland tropical forest in the Southeast Asian region.

Keywords: Primary productivity, ecosystem exchange, autotrophic respiration, biome production, carbon balance, biosphere-atmosphere fluxes

INTRODUCTION

Net ecosystem productivity (NEP) is an important ecosystem characteristic because it integrates the activities of all organisms living in an ecosystem. It summarizes the entire carbon/energy flux of an ecosystem and is an important determinant of the global carbon cycle (Sprugel 1985). The negative value of NEP caused by the death of big trees increased carbon release rates through decomposition of fresh mass litter (Vitousek & Reiners 1975; Yoneda 1997, 2003). Previous studies on primary productivity and carbon cycling had been intensively conducted in this 2 ha of Pasoh, Peninsular Malaysia under the International Biological Program (IBP) during 1970-1974 (Kira 1978, 1987) using the biometric method and observation using Eddy Covariance method has been continued in this stand since 2003. Annual NEP at a 2 ha stand ranged from −5.0 t Carbon ha^{-1} y^{-1} to 2.1 t Carbon ha^{-1} y^{-1} during the last 43 years (1969-2012) with two times depressions (Yoneda et al. 2016). They were caused by man-made and natural disturbances (majorly drought and storms) that affected as much as 10% of the 2-ha stand area, and negative NEP was maintained around 10 years after disturbances (Yoneda et al. 2016 & 2017). NEP has a negative value when carbon loss exceeds carbon input and act as a carbon source and positive value carbon input exceeds carbon loss and acts as a carbon sink.

The average NEP and carbon stocks in biomass and coarse woody debris over 15 years from 1990 to 2005 were −0.75 t C ha^{-1} y^{-1}, 205 t C ha^{-1}, and 22 t C ha^{-1}(Yoneda et al. 2017). It was suggested that NEP of a forest ecosystem was largely influenced by large variances of supply rates of Coarse Woody Debris/ Litterfall ranging from 1.6 t C ha^{-1} y^{-1} to 10.3 t C ha^{-1} y^{-1} (Kira 1987). There are four main components for estimating NEP (Figure 1), i.e.: annual living biomass increment, annual dead biomass storage, biomass consumed by herbivores, and heterotrophic respiration. Annual living biomass increment includes both belowground and aboveground biomass. Studies on living biomass increment of the aboveground compartment have been widely carried out based on allometric models that employ any three predictor/variables namely diameter at breast height (DBH), height (H) and/or wood density/wood specific gravity (ρ). Dead biomass storage of fine roots is estimated by the continuous inflow method (Osawa & Aizawa 2012). While the dead biomass of coarse roots is quite small, and it is usually ignored in estimating NEP. In addition, biomass consumed by herbivores is also ignored because it is known as negligible and rather difficult in estimation (Clark et al. 2001). The study aimed to quantify carbon fluxes in all pools and net carbon accumulation of forest under the pristine condition in lowland dipterocarp forest in Malaysia; and to estimate the metabolic status of terrestrial ecosystem whether it is a net autotrophic (production exceeds respiration) or net heterotrophic (respiration exceeds production).

MATERIALS AND METHODS

Study Site and Location

Pasoh Forest Reserve (N 02′ 58.142″, E 102′ 17.820″) is located in Negeri Sembilan, (approximately 70 km southeast Kuala Lumpur city centre) covering a total area of 1,840 hectares gazetted for research and educational purposes (Figure 1).

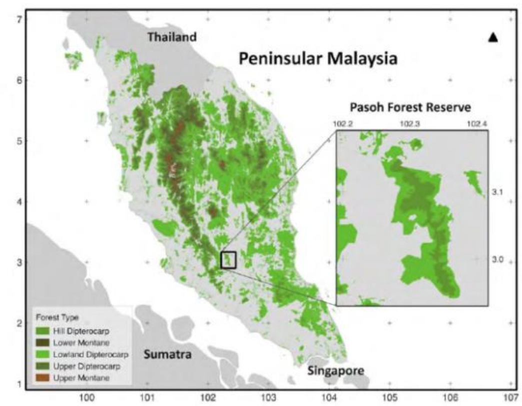

Figure 1 Pasoh Forest Reserve is one of the FRIM research stations

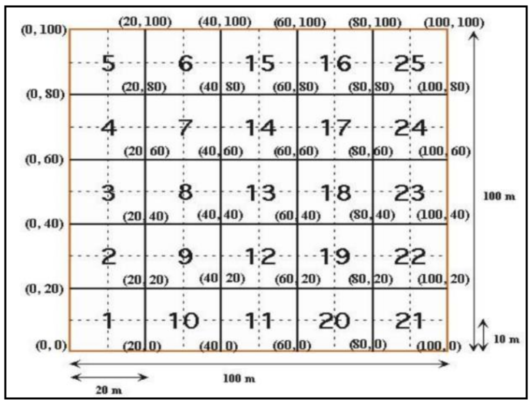

Figure 2 The subplots in the vegetation plot and subplot numbers. GPS Coordinate: VGPSH1P. (102.30515º N, 2.98084º E).

Field Experiment and Data Collection

In a 1 ha study area consist of twenty-five (25) subplots of 20m x 20m study plot, all stems with DBH (diameter at breast height) ≥ 5 cm were measured in 1 year intervals and identified to species level for aboveground living biomass increment (△M).

Calculation Method

Net Ecosystem Production (NEP) or Carbon accumulation of forest (CAF) or rate of carbon accumulation in a forest ecosystem is simply estimated in Eq. 1 (O'Connell et al. 2003).

NEP = NPP – Rs **[1];**

where NPP is net primary production and Rs is heterotrophic respiration (soil respiration).

NPP Estimation

There are four compartments included in NPP, where △M is aboveground living biomass increment, △Cr is coarse root increment, Lf is aboveground litterfall, and Pr is fine root production.

NPP=ΔM+ΔCr+Lf+Pr **[2];**

Firstly, the aboveground biomass AGB; kg dry weight) of each stem were estimated based on allometry according to Chave et al. (2005)

[Aboveground Biomass (kg)= ρ x exp (-1.499 + 2.148 x ln DBH + 0.207 x $(\ln(DBH))^2$ – 0.0281 – (ln $(DBH)^3$)] **[3];**

Following suit, the coarse roots were also estimated using equation adopted from Niiyama et al. (2010) for Malaysia

$W_B = 0.023 * D^{2.59,}$ where W_B is belowground biomass and D is DBH. **[4]**

Conversion to Carbon

NPP is first estimated as dry biomass (Mg/ha/year), then is converted to carbon (Mg C/ha/year) as equalled to 50% of dry biomass (Sarmiento et al. 2005). Meanwhile, Rs is measured µg mol CO_2 m^2 s^{-1} and indirectly converted to carbon (Mg C/ha/year) using molecular weight (µg mol^{-1}) of the measured CO_2 gas. The difference between NPP and Rs referred to ecosystem production in this case is carbon accumulation (Mg C/ha/year).

RESULTS AND DISCUSSION

General Characteristics

The total number of trees was 1474 ha^{-1} with 122 families and 235 species were enumerated and recorded (Table 1). Aboveground biomass and carbon stocks were calculated based on flora inventory. The major and most abundant (based on individual presence) botanical families recorded were Dipterocarpaceae, Fagaceae, Myrtaceae, Sapindaceae, and Burseraceae with trees ranging from 4 to 68 m in crown height and DBH ranging from 5 – 144 cm. Table 1 shows the summarized information for the forest plot. The largest stem was 144 cm in DBH and the mean DBH of the forest stand was 9.3 cm (Table 1).

Table 1 General characteristics of study forest

Item	Values
Stem density (stems ha^{-1})	1474 ± 50
Mean DBH (cm)	9.3 ± 1.3
Max DBH (cm)	144
Basal area (m^2 ha^{-1})	29.59 ± 1.3
Total NPP (Mg C ha^{-1} $year^{-1}$)	7.30
Soil respiration (Mg C ha^{-1} $year^{-1}$)	7.52
Total NEP (Mg C ha^{-1} $year^{-1}$)	-0.22

Total Net Primary Production

The total NPP estimated from this study was 7.30 Mg C ha^{-1} $year^{-1}$ which is lower in comparison to a previous study in Sarawak (west Peninsular Malaysia) at 12.85 Mg C ha^{-1} $year^{-1}$ (Kho et al. 2013). The aboveground biomass was 144.23 Mg C/ha (in 2018) is slightly lower than the previous study by Ngo et al. (2013) in a primary forest plot in Bukit Timah, Singapore which is 167.5 Mg C/ha/year. There is evidence suggesting substantial variation in aboveground allocation of NPP across tropical forest sites, with a very different relationship for Asian forests (Malhi et al. 2011). Therefore, quantification and understanding of productivity, its allocation, and their response to climate in terms of seasonality are crucial in a lowland dipterocarp forest like Pasoh FR.

Table 2 Estimates of Net Primary Production and Net Ecosystem Production of Pasoh Forest Reserve

Variables	Year 2018 (Mg C/ha/yr)	Year 2017 (Mg C/ha/yr)	NPP increment
Aboveground biomass (M)	144.23	143.00	1.23
Coarse roots (C_r)	3.95	3.96	0.00
Litterfall (L_f)	3.10		3.10
Fine roots (F_r)	2.97		2.97
Total			**7.30**
Root respiration (R_s)	7.52		
Net Ecosystem Production (NEP)	**-0.22**		

Heterotrophic Respiration from Soil

Soil CO_2 fluctuations (µmolm^{-2} s^{-1}) ranged as follow; morning (1.446 -1.7222), noon (1.955-3.115), evening (1.298-3.392), night (average 2.853) and control (2.0189) respectively (Figure 3) with chamber CO_2 concentration above 374 µmolmol^{-1} at 3 cm insertion collar depth. Factor/variables such as soil temperature and moisture had effects on soil CO_2 efflux. Soil temperatures varied from 25^o to 26 ^oC during the measurements. Measurements were made during the dry season period (August 2017). Soil and mean air temperature accelerate organic matter decomposition by microbes due to favourable environmental conditions and contribute to soil respiration (Jeyanny et al. 2015). The yearly mean of soil respiration in lowland dipterocarp forest in Peninsular Malaysia was 2.72 $gCm^{-2}day^{-1}$, equalling 7.52 tons C ha^{-1} $year^{-1}$.

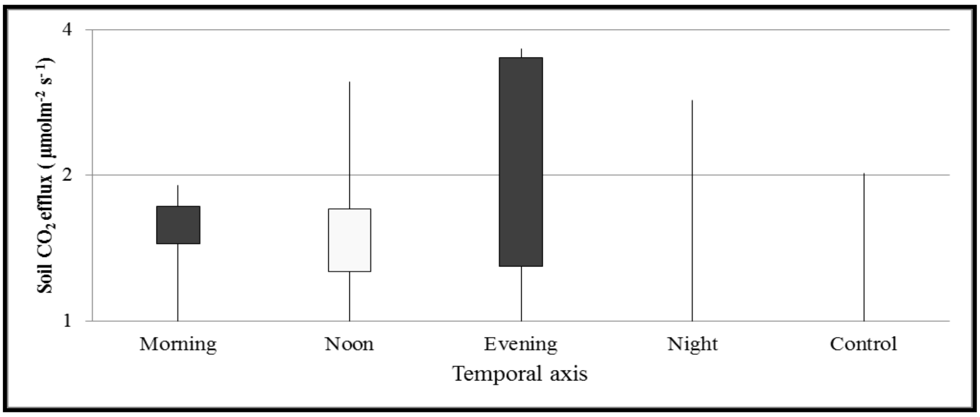

Figure 3 Soil CO_2 flux measurement in Pasoh FR for trenched and control (untrenched)

CONCLUSION

The NEP value was –0.22 Mg C/ha. NEP has a negative value when carbon loss exceeds carbon input indicated as a carbon source in an old-growth forest with a mature stand between 2017 and 2018. The metabolic status of Pasoh Forest Reserve as net heterotrophic, whereby respiration activity exceeds production at the ecosystem level. Frequency/Intervals of data collection, uniform method, and reliability of equipment will ensure field measurement accuracy for NEP estimation.

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ESTIMATING NET ECOSYSTEM PRODUCTION OF TROPICAL FORESTS OF JENGKA, FOREST RESERVE, PAHANG

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Net Ecosystem Production (NEP) and/or carbon accumulation is a fundamental property of ecosystems. NEP covers several components such as living biomass (trees), coarse roots, fine roots, litterfall, and soil respiration. This is the first study to depict NEP in Jengka Forest Reserve, Pahang from 2017- 2018. The remaining data for 2019 and 2020 are being analysed. In order to capture this information, a study was conducted to determine changes in aboveground and belowground biomass growth using allometric equations, fine roots dynamics using root bag experiment and root coring method; collection of litterfall using litter traps and determination of heterotrophic and autotrophic respiration with LiCor 8100A-an automated soil carbon dioxide flux system. The results indicated that one hectare of broad-leaved forest in Jengka Pahang, Malaysia had a Net Primary Production (NPP) value of 6.80 Mg C ha^{-1} year^{-1}. The results also showed a slight increment in above-ground biomass from year 2017 to 2018, almost 1 Mg C ha^{-1} year $^{-1}$ whereas the NEP was equivalent to – 2.10 Mg C ha^{-1} year^{-1}, as a carbon source. The NEP for tropical forests although are known as carbon sinks, may differ according to disturbances, spatial and temporal variations. The data shown here is only for a year and continuous monitoring will assist long term monitoring works.

Keywords: Carbon allocation, tropical broad leave forest, net primary production, climate change

INTRODUCTION

Net Ecosystem Production and/or carbon accumulation (NEP) is a fundamental property of ecosystems. It was originally defined by Whittaker & Woodwell (1968) as the difference between the amount of organic carbon fixed by photosynthesis in an ecosystem and total ecosystem respiration. Based on this definition (Fig. 1 in Appendix), NEP represents the organic carbon available for storage within the system or loss from it by export or non-biological oxidation. In other ways, NEP is known as the rate of carbon accumulation in forest ecosystem (Randerson et al. 2002). NEP covers several components such as living biomass (trees), coarse roots, fine roots, litterfall, and soil respiration.

MATERIALS AND METHODS

The research was carried out in a secondary lowland forest in Pahang, West Malaysia. This site was chosen as secondary data were available from the previous studies (Jeyanny et al. 2014). It is known as Jengka Virgin Jungle Reserve (Jengka VJR), Jengka 18, Pahang (N 3˚ 34.99' 102˚ 34.29' E) located at 50 – 90 m asl with slope ranging from 2- 8°with soils derived from Durian soil series. Six plots measuring 10 m x 10 m were laid out. In the study plot, all stems with DBH (diameter at breast height) > 5 cm were measured and identified to species level in Decembers 2017 and 2018 for aboveground living biomass increment (ΔM) estimation. Similarly, the coarse roots increment (ΔCr) was also estimated for both years. Twenty litter traps, 1 m x 1 m dimension, 1 meter from the ground were established systematically within the plots to collect litterfall every 4 months. Samples were oven dried at 80°C and the oven dry mass recorded periodically.

Fine roots were collected in bulk outside of the designated plots at 20 cm soil depth using a 150 mm length and 80 mm in diameter soil coring probe for root bags preparation. Roots were washed, air dried and oven dried at 80°C and were inserted into 120 root bags amounting to 1.0 g each. Root bags were buried to 10 – 15 cm soil depth and collected at corresponding time intervals, at every 4 months. Collected root bags were washed, and then oven-dried for remaining mass. γij is estimated as equaling (initial mass - remained mass)/initial mass. Root bags (n=18) were collected up to 1 year (120 days; 240 days: 360 days) and processed. At the given time, litter collections (traps) and soil cores up to 20 cm collected. Collected fine roots were air-dried, then separated to living and dead roots (Hishi & Takeda 2005), and oven-dried at 80°C until constant for weight of living roots (called fine root biomass) and that of dead fine roots (called necromass).

The estimation of carbon accumulation of forest (CAF), net primary production (NPP) and net ecosystem production (NEP) were done according to Do & Sato (2018). Soil respirations were done according to Jeyanny et al. (2021).

RESULTS AND DISCUSSION

Based on our results, it was displayed that there was a slight increment in (M) from year 2017 to 2018, almost 1 Mg C ha^{-1} year $^{-1}$ (Table 1). The (Cr) fraction was very minimal and the (Lf) fraction showed increment of 3.94 Mg C ha^{-1} year $^{-1}$. Fine roots production (Fr) showed an increment of 1.64 Mg C ha^{-1} year $^{-1}$. Our results for (Fr) concur with of Violita et al. (2016) in Jambi Province in a lowland rainforest. The total NPP was Mg C ha^{-1} year $^{-1}$, (Table 1) whereby Lf accounted the highest percentage 57.9 % followed by Fr (24.3 %). Do & Sato (2018) reported similar trends where Lf and Fr constituted the biggest portions in ever-green broad leave forest in Japan. Our results showed a negative NEP which reports that Jengka FR was a source of carbon between 2017 and 2018. This was possibly due to the location which was a fragmented forest surrounded by other agricultural crops plantations such as rubber and palm oil in adjacent areas.

Table 1 Net Primary Production and Net Ecosystem Production of Jengka Forest Reserve

Variables	Mg C ha^{-1} $year^{-1}$ Year 2018	Year 2017	NPP increment	Ratio (%)
Aboveground biomass (M)	92.87	91.89	0.98	14.4
Coarse roots (Cr)	33.19	32.96	0.23	3.4
Litterfall (Lf)	3.94		3.94	57.9
Fine roots (Fr)			1.64	24.3
Total			6.80	**100**
Soil respiration (Rs)	8.9			
Net Ecosystem Production (NEP)	(-) 2.1			

CONCLUSION

The NEP for tropical forests although are known as carbon sinks, may differ according to disturbances, spatial and temporal variations. The data shown here is only for a year and continuous monitoring with additional funding will assist long term monitoring works. Based on this unique ecosystem, it was estimated that NEP values were negative, constituting that the area was a carbon source rather than a carbon sink. The biggest fraction that constituted NPP was litterfall and fine root production. The dynamics of fine root production change according to seasonal variation. Our data collected in 2019 and beyond is still going through analysis and will be presented once analysis has been done.

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TREE SPECIES AND SOIL CARBON IN THE MAK JINTAN PEAT SWAMP FOREST, KUALA NERUS, TERENGGANU

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Mak Jintan Peat Swamp Forest (MJPSF) is a state land forest area under the jurisdiction of Kuala Nerus District and Land Office, Terengganu. This forest was discovered in the year 2016 during an assessment of High Conservation Value (HCF) conducted by WWF-Malaysia and Daemeter Consulting Group. MJPSF is adjacent to the Belara Forest Reserve and oil palm plantations with cover an area of 703.83 ha. Ecological studies are needed for MJPSF to provide imperative information on the forest structure and environment. The information is deemed useful for future management of this area. In the light of conservation, WWF-Malaysia and Forest Research Institute Malaysia (FRIM) have initiated a study at MJPSF. The key aspects of the study are tree inventories, soil carbon assessment, and forest mapping. Eight line transects were established randomly at MJPSF. Each transect consists of three circular plots with a 10 m radius. As a result, a total of 473 trees of $\geq$ 10 cm diameter-at-breast-height (dbh) were enumerated in this study. Besides that, the forest area is a habitat for 63 tree species which belong to 52 genera and 32 families. Among high-quality value timber species of peat swamp forest recorded in this study were meranti paya (*Shorea platycarpa*), keranji (*Dialium* sp.), bintangor (*Calophyllum ferrugineum*) and nyatoh (*Palaquium* sp.). The soil carbon for MJPSF is averaged at 163.20 tC/ha. Findings from this study will provide valuable insights for peat swamp forest management in Malaysia and encourage more conservation efforts and projects within MJPSF in the future.

Keywords: Peat swamp forest, species composition, soil carbon, peatland

INTRODUCTION

Peat is described as an organic soil, which is formed from the accumulation of dead leaves and other plant materials that partially decomposed under waterlogged conditions due to the oxygen-deficient conditions. In Malaysia, peat is defined as soil with high organic matter content (more than 65%) in a soil layer at least 50 cm deep (NRE 2011). Areas where peat soil naturally accumulated are called peatlands, while swamp forest growing on peatland is called peat swamp forest (PSF) (D'Cruz 2014).

Peat is one of the soil types in Malaysia covering about 8% of the total land in Malaysia (NRE 2011). Peatlands are the most widespread type of wetlands in Malaysia, occurring in more than 8 of the 13 states, namely Johor, Kelantan, Perak, Pahang, Sabah, Sarawak, Selangor, and Terengganu. Recent data on peatland cover and status in Malaysia is inconsistent and varies among different agencies and stakeholders at both national and state level (UPM 2014). According to the International Fund for Agricultural Development (IFAD) (2017), it is estimated that the total peatland area in Malaysia is approximately 2.7 million hectares, and the majority (60.7%) is in Sarawak. Around 28% of the total peatland areas in Malaysia remain under forest cover while the remaining have been converted for other purposes, and some areas are designated as state land forests (IFAD 2017).

Mak Jintan Peat Swamp Forest (MJPSF) is a state land forest under the jurisdiction of Kuala Nerus District and Land Office, Terengganu. This area is situated around 60 km from Kuala Terengganu and 50 km from Setiu Wetlands. MJPSF is a newly detected PSF in Terengganu. It was discovered during an assessment of High Conservation Value (HCV) which was conducted by WWF-Malaysia and Daemeter Consulting Group in 2016. To date, there were no ecological studies were conducted in MJPSF. Therefore, the objective of this study was to provide baseline information on the forest structure and environment which is deemed useful for future management of this area.

MATERIALS AND METHODS

Study Area

MJPSF is adjacent to the Belara Forest Reserve and oil palm plantations with a cover area of around 703.83 ha. The adjacent forest which consists of lowland dipterocarp forest, with undulating terrain is totally different from the PSF ecosystem. Based on forest classification analysis run prior to field activities, MJPSF has been classified as an intact forest with a high FCD (forest canopy density) value ranging from 0.6 (60%) to 0.8 (80%). Accessibility into the MJPSF is difficult due to its location. To reach the designated GPS point, a few private plantation areas owned by smallholders and companies need to be traversed. Access to the forest boundary areas is achievable with help from locals who are very skilful with the in and out of the private plantation areas.

Inventory Method and Design

a) Tree survey

Eight line transects (A, B, E1, E2, F, G, H, K) has been established at MJPSF. Each line transect has three or five sample plots in a circular shape. The distance between the 2 sample plots (midpoint to midpoint) is 30 m apart. Each sample plot had a 10 m radius which gives a plot size of about 0.03 ha. Transect line and sample plots layout as in **Figure 1**. In this plot, all trees with a diameter at breast height (dbh) 10 cm and above were enumerated. Information such as tree species, local name, dbh (cm), and tree height (m) was recorded. Leaf samples were taken if species identification at the site was unsuccessful. The leaf samples will be brought to FRIM herbarium for further identification process. Altogether, a total of eight line transects (33 sample plots) have been established in the study area.

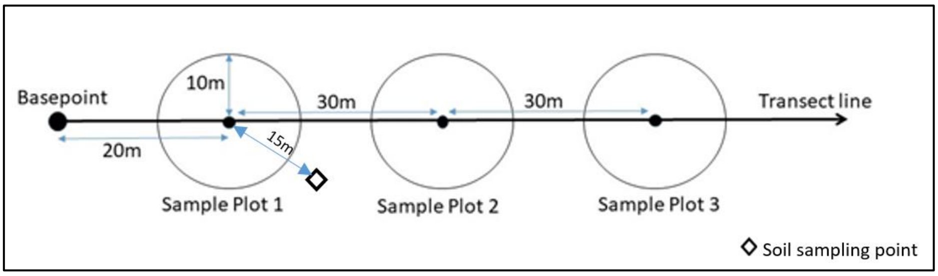

Figure 1 Transect line and sample plots layout

All trees enumerated in the sample plots were summarised for overall taxonomic composition and quantitative data were analysed to determine abundance. These include the determination of basal area, as well as calculating the density and frequency of occurrence of each species. Tree basal area (BA) was calculated using the equation as follows: $BA = [\pi \times (d^2)/40000]$ (unit: m^2), where d is the dbh and π=3.142. The Importance Value Index (IVI) was also calculated to determine the species importance of the forest. The IVI was calculated by summing up the values of relative density (RD), relative dominance (based on basal area) (RDm), and relative frequency (RF) of each species or family [IVI = RD + RB + RF)/3].

b) Soil carbon

Soil samples were collected 15 m in distance from the midpoint of the circular flora plot (Figure 1). The sampling activities were done according to the standard operating procedure by Winrock International (Walker et al. 2012) which has been modified to suit PSF conditions. Each transect consists of three samples. A core sample was collected at a standard 30 cm depth and 100 g sample of peat soil was collected for organic carbon analysis. Core samples were oven-dry at a constant temperature of 95^{o}C for 48 hours and the dry mass was used to obtain the bulk density. Peat soil samples were then analysed at the soil laboratory to determine the percentage of organic carbon.

Calculation of soil carbon was derived from certain calculations referring to a module by Winrock International. Equations (1) and (2) were used to calculate soil carbon.

$$BD_{soil} = \frac{DM}{Vol_{core}} \qquad (1)$$

Where, BD is soil bulk density in g/cm^3, DM is dry mass of soil in gram and Vol_{core} is mineral soil core volume in cm^3.

$$C_t = BD_{soil} \times Depth_{soil} \times C_{soil} \qquad (2)$$

Where, C_t is soil carbon (t C/ha), BD_{soil} is soil bulk density in g/cm^3, $Depth_{soil}$ is soil depth in cm and C_{soil} is percentage of organic carbon.

All these calculations are used to assess the total soil carbon per unit area. Means of soil carbon were analysed for each transect.

RESULTS AND DISCUSSION

Species Composition

A total of 476 trees of 10 cm dbh and above were enumerated in the study areas. The result indicated that a total of 63 species of trees belong to 52 genera and 32 families were found in the area surveyed. The Euphorbiaceae was the largest family with 6 species, followed by Annonaceae (5 species), Guttiferae and Moraceae (4 species each), Elaeocarpaceae, Lauraceae, Myrtaceae and Sapotaceae (3 species each), Anacardiaceae, Dipterocarpaceae, Leguminosae, Malvaceae, Meliaceae, Myristicaceae, Phyllanthaceae and Rubiaceae (2 species each) and the remainder have one species each. Apparently, the findings of this study were quite similar to the results from the previous studies. A comparison of finding from this study with previous studies at different PSF sites is summarised in Table 1.

Table 1 Findings of PSF species composition / diversity studies in Malaysia

Site	Findings / Results	Source
Compartment 156, Pekan Forest Reserve, Pahang	68 tree species from 26 families (above 10cm dbh ; 1 ha plot)	Ismail Parlan *et al*. (2009)
Compartment 200, Pekan Forest Reserve, Pahang	100 tree species from 37 families (above 10cm dbh ; 1 ha plot)	Ismail Parlan *et al.* (2009)
Post-felling inventory at Pekan Forest Reserve (2,156 ha)	67 tree species occurring at surveyed area.	Grippin (2005) cited in Ismail Parlan *et al.* (2009)
Kuala Langat VJR, Selangor	54 tree species from 27 families (above 5cm dbh)	Shamsudin & Chong (1992) cited in Appanah *et al.* (1999)
North Selangor PSFs	107 tree species from 27 families (above 5cm dbh)	Hahn-Schilling (1994) cited in Appanah *et al.* (1999)
Ayer Hitam North PSF, Johor	70 tree species from 31 families (above 10 cm dbh)	Hyrul Izwan *et al*. (2021)
Mak Jintan PSF, Terengganu	63 tree species from 32 families (above 10cm dbh)	This study

Abundance and Distribution

Parameters for abundance such as density and basal area are essential to define forest structure (Ismail et al. 2009). The species density gives an idea about the strength of a species in the community. The total stem density estimated in the study area was 457.67 tree ha^{-1}. Five species with the highest density were *Macaranga pruinosa* (53.85 trees ha^{-1}), followed by *Syzygium napiforme* (34.62 trees ha^{-1}), *Syzygium cerinum* (28.85 trees ha^{-1}), *Xylopia fusca* (25 trees ha^{-1}) and *Artocarpus kemando* (25 trees ha^{-1}). According to Saw (2010), a high density of *M. pruinosa* in a certain community is an indicator that the forest is disturbed or has been logged over. This result may be contributed by the location of the transect lines which mostly lies near the forest edge. Most of the base points of the transect line are located approximately 50 m from the forest edge. However, notable tree species such as meranti paya (*Shorea platycarpa.),* keranji (*Dialium sp*.), bintangor (*Calophyllum ferrugineum*), and nyatoh (*Palaquium sp*.) which have been described by

Appanah et al. (1999) and Khali Aziz et al. (2007) as a high-quality timber species in PSF were also recorded in the study area, yet with lower stand density value. It is expected that if more sample plots were established further inside the forest and/or the establishment of a few plots on the east side of MJPSF, more commercial and important species can be recorded.

The basal area is an important parameter for understanding the dominance of trees in an ecosystem (Srinivasa et al. 2013). The total tree basal area for the study area was 21.9 m^2ha^{-1}. The basal area ranged from 0.01 to 2.71 m^2ha^{-1}, showing the highest for *M. pruinosa* (2.71 m^2ha^{-1}) and the least for *Prunus arborea* (0.01 m^2ha^{-1}). Basal area for notable species such as *S. platycarpa*, *C. ferrugineum*, *Dialium indum*, and *Palaquium sp.* were 0.20, 0.02, 0.47, and 0.66 m^2ha^{-1} respectively. Comparing the basal areas of trees from this study with other studies in other PSFs in Malaysia, it is likely that the result at MJPSF is almost similar to those reported by Ismail et al. (2009) at Compartment 156 (33.44 m^2ha^{-1})' Compartment 200 (26.54 m^2ha^{-1}) at Pekan Forest Reserve and by Hyrul Izwan et al. (2021) at Ayer Hitam North Forest Reserve, Johor (24.48 m^2ha^{-1}).

The dominance of a species in a community is expressed through the species Important Value Index (IVI) which incorporates the values of relative density (RD), relative dominance (based on basal area) (RDm), and relative frequency (RF) of each species for measuring the productivity and diversity of each species (Saurav & Das, 2014). The species with greater IVI is the important dominant species in the area of study. From the analysis, IVI for the study area ranged from 0.28% to 9.20%. The most dominant species was *M. pruinosa* (9.20%) followed by less dominant species such as *S. napiforme* (6.15%), *S. cerinum* (5.07%), *X. fusca* (5.00%), *A. kemando* (4.92%) and others. Ten most dominant species based on the highest IVI at MJPSF are shown in Table 2.

Table 2 Abundance parameters for 10 important species that are ranked based on its IVI in MJPSF.

No	Species	F (%)	D	Dm	Rd	RF	RDm	IVI (%)
1	*Macaranga pruinosa*	75	53.85	2.71	11.77	3.45	12.39	9.20
2	*Syzygium napiforme*	100.00	34.62	1.37	7.56	4.60	6.28	6.15
3	*Syzygium cerinum*	62.50	28.85	1.32	6.30	2.87	6.02	5.07
4	*Xylopia fusca*	87.50	25.00	1.21	5.46	4.02	5.52	5.00
5	*Artocarpus kemando*	87.5	25.00	1.16	5.46	4.02	5.29	4.92
6	*Parartocarpus venenosa*	75.00	14.42	1.65	3.15	3.45	7.55	4.72
7	*Stemonurus secundiflorus*	100.00	29.81	0.56	6.51	4.60	2.57	4.56
8	*Litsea sp*	62.50	21.15	1.07	4.62	2.87	4.88	4.13
9	*Horsfieldia crassifolia*	50.00	19.23	0.98	4.20	2.30	4.47	3.66
10	*Quassia indica*	87.50	18.27	0.53	3.99	4.02	2.42	3.48

[F= Frequency (%), D= Density (trees ha^{-1}), Dm= Dominance (basal area, m^2ha^{-1}), RF= Relative frequency, RD= Relative diversity, RDm= Relative dominance, IVI= Important Value Index]

Stand Structure

The distribution of tree diameter classes contributes to the structural pattern and characteristics of the rainforest (Ismail et al. 2009). In this study, MJPSF displayed the inverse J shape where stem frequencies decrease with the increase in dbh (Figure 2). This suggested MJPSF has a normal distribution pattern of rainforest, with a high density of trees at the lower diameter class and gradually declines with bigger diameter classes which indicated that the stands are developing and regeneration present. Natural regeneration is dependent on the availability of the mother trees, fruiting patterns, and favourable conditions (Mohd Nazip 2012). Under natural conditions, an old, big emergent tree may fall and a great gap thus natural succession will take place if the area is close enough to mature primary forest trees serving as a source for recalcitrant seeds (Mohd Nazip 2012). Ismail et al. (2009) also described the same inverse J pattern on the distribution of tree diameter class at Compartment 156 and Compartment 200 of Pekan Forest Reserve. Mohd Nazip (2012) also found the same pattern of distribution of diameter class for lowland forest at Kuala Keniam Forest, Pahang National Park.

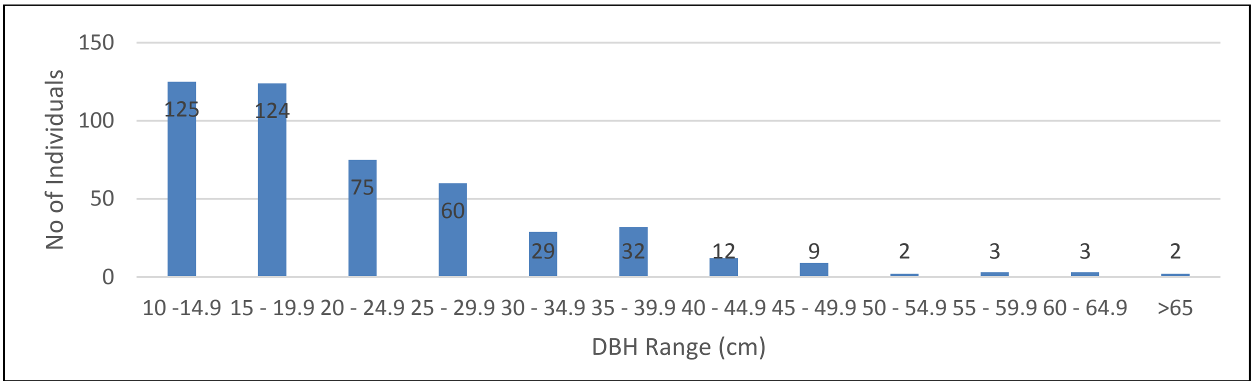

Figure 2 DBH distribution of trees at MJPSF

Soil Carbon

The means of soil carbon for all transects in MJPSF is shown in Figure 3. The least mean soil carbon was discovered at transect A (83.49 tC/ha) while the largest was found at transect K (258.88 tC/ha). The average soil carbon for MJPSF is calculated at 163.20 tC/ha. This value is comparable to the previous study for vegetated PSF areas in VCOS (Voluntary Carbon Offset Scheme) sites in Sungai Bebar and Sungai Merchong in southeast Pahang Peat Swamp Forest where the soil carbon stock at 30 cm depth was 247 tC/ha (FRIM 2017). Depth of sample plays an important role in determining the value of soil carbon in PSF. A study by Warren et al. (2012) showed that the carbon stock for peat soil in Danau Sentarum National Park, Sabangau Natural Laboratory of Peat Swamp Forest, and Berbak National Park of Indonesia were recorded ranging from 1,424.61 - 5,709.60 tC/ha with average sampling depth from 2.28 m to 12.07 m.

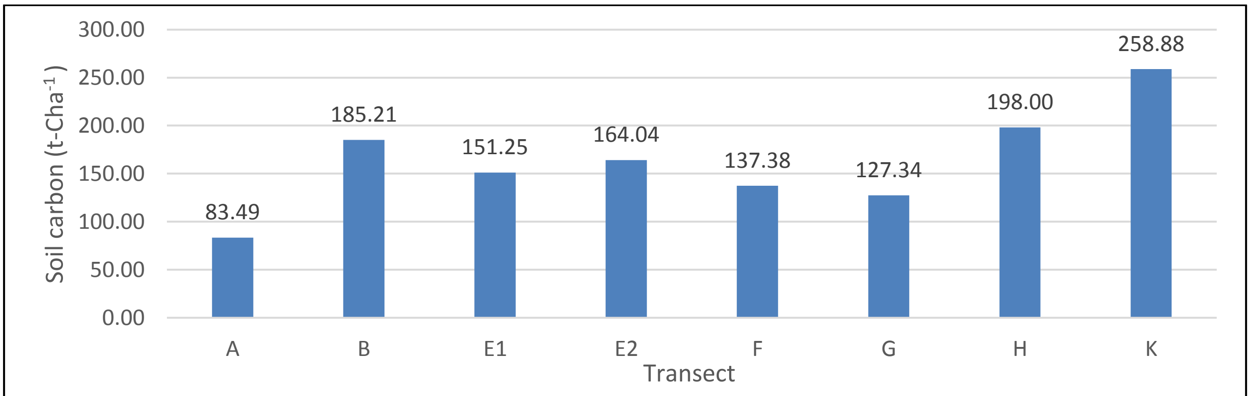

Figure 3 Means of soil carbon for each transect of MJPSF

CONCLUSION

MJPSF was discovered in 2016 and currently, not much ecological information is available for this area. Based on this study, MJPSF has relatively dense canopy coverage, diverse tree populations and contains high soil carbon content. Further study is required for a better understanding on the dynamic of the PSF ecosystem at MJPSF especially the hydrological, peat soil (including depth), detailed flora and fauna, carbon contents as well as community aspect. The baseline data provided by this study may assist the relevant agencies in drawing up future planning and action to conserve and manage this precious forest.

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THE ASSESSMENT OF ABOVE-GROUND BIOMASS ATTRIBUTES AND CARBON STORAGE OF *AQUILARIA MALACCENSIS* PLANTATION

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By an increased number of agarwood plantations nowadays, trees also enhance CO_2 levels in the form of wood, thus plantation serves as a carbon reservoir on the ground providing one of the important roles in mitigating global warming. This study was carried out to access tree growth performances and to determine the above-ground biomass and carbon storage of 10-year-old planted *Aquilaria malaccensis*. A total of 418 trees from one-hectare plot were inventoried. Height (H) and diameter at breast height (D) were measured and grouped into three class diameters. Ten trees from these diameter classes were destructed randomly by using a random sampling method to develop allometric equations for estimating the total above-ground biomass and carbon storage. The total above-ground biomass in this one-hectare plot using D function was estimated at 23.6 Mg. The average carbon content was 40.35%. The average carbon density in this *A. malaccencis* plantation was 28.5 kg tree^{-1} and 9.6 Mg ha^{-1}. A total of 1046.4 kg CO_2 from observation trees has sequestered. These findings might become a reference for agarwood treatment preparation and estimated carbon dioxide sequestered by *A. malaccensis* plantation.

Keywords: Aboveground biomass, agarwood, *Aquilaria malaccensis*, carbon storage, allometric equation

INTRODUCTION

Aquilaria spp. is one of the most fascinating non-timber forest products in the world where the resin impregnated in the wood was producing agarwood (Persoon 2008). Consequently, there is an increasing demand for high grade agarwood in the global market led to the increase of agarwood plantations. Many studies have reported a reduction of the natural populations in Peninsular Malaysia (Lilian 2008). Harvesting of agarwood from the natural forest is posing a threat to the agarwood-producing species (Nor Azah 2013).

Destruction of trees for agarwood determination is a simple method that is often used. This condition causes a lot of trees would be cut down to get a return which was indirectly decreasing the carbon pool in the existing plantation. It is important to assess the environmental effects of *Aquilaria* plantation in relation to the dynamics of biomass and carbon (Shidiq et al. 2017). There is limited information about biomass distribution and carbon stocks of *A. malaccensis* in the established plantation. Above-ground biomass (AGB) estimation using species-specific equations is preferred because trees of different species may differ significantly in tree architecture and wood density (Iqbal et al. 2020). A method using the allometric equation has been developed by many researchers to predict biomass given some easily measurable predictor variables, including fast-growing tropical species (Khan et al. 2020).

This study was conducted to assess the above-ground biomass (AGB) and carbon stock by establishing a specific allometric equation for this species. The findings perhaps could provide basic information on how monoculture plantation contributes to sequestering carbon via biomass estimation.

MATERIALS AND METHODS

This study was performed at FRIM Research Station at Kg. Ulu Luit, Maran Pahang. *A. malaccensis* trees were planted in two and a half hectare areas since 2008 with planting spacing at 4 m x 4 m (about 625 trees ha^{-1}). Tree census was conducted in a one-hectare plot where 418 trees were found to survive. The trees were grouped into three diameter classes namely small (up to 15 cm), medium (15 to 25 cm) and big (above 25 cm) size based on tree census data. Ten trees were selected using a random sampling method based on normal distribution statistics of (D) to represent all diameter classes. Weighing and recording of the fresh sample data of disk logs, leaves, and branches-twigs were done in the field before they are being brought to the laboratory to be oven-dried at 75 ^{o}C to the constant weight of the component (about 7 days for the stem and 4 days for the other components), to calculate dry weight conversions.
The total dry weight of the components which is representing the aboveground biomass (M_i) as follows (Heryati et al. 2011):

$$TDW = \frac{SDW \times TFW}{SFW} \quad \text{where, } TDW = M_i$$

The aboveground biomass (AGB) was determined by calculating the sum of the biomass components as follow;

$$AGB = \sum M_i$$

The relationship between the independent variable and the biomass of components was described by a power function using the following allometric relationship based on the coefficient of determination (R^2):

$$M_i = a\,(D)^{b} \quad \text{where, } a,b = \text{constants}$$

Individual tree was analyzed by LECO CR-412 Carbon Analyzer (LECO Inc., US) for carbon density estimation. The dry weight sample was then converted as a percentage of carbon content.

$$AGC = \sum M_i \times C_i$$

Where, AGC = Aboveground carbon, C_i = the amount of obtained carbon content components
The carbon stock value was then multiplied with the weight of carbon in the tree by 3.6663 which is the ratio of CO_2 to C to determine the weight of CO_2 sequestered.

RESULTS

Descriptive statistics and analysis of variance of the *A. malaccensis* from a one-hectare study plot in FRIM Research Station, Maran were illustrated in Table 1. There was a highly significant difference ($p < 0.01$) distribution between the diameter class and tree height. Diameter class 2 dominating the distribution of one-hectare plot area with a total number of individual trees was 248 followed by diameter class 1 (122) and diameter class 3 (48) as in (Figure 1). Biomass regression derived from 10 destructive samples of *A. malaccensis* with three diameter classes of D and H were illustrated in Table 2. Allometric models for estimating the tree component and total aboveground biomass were based on parameter D (Figure 2). The allometric equation was determined by a large R^2 value with a small standard error and found in developed equations model using D. The developed equations of 10 destructive samples were regressed between observed value (data collected from the field) and estimated value (model application), as illustrated in Figure 3. The coefficient of determination of R^2 was large (>90%) in all developed equation models. Tree components from stem, branch-twigs, and leaf contributed 311.9, 264.4 and 131.0 kg biomass respectively. The total observed AGB value from the field was 707.3 kg from ten destructed trees. When applying the developed equations on conducted area, the estimation of total AGB value was 706.7 kg by equation no.4. The developed equation used to check the internal consistency of the allometric relationships by comparing observed and estimated values was then applied to a large data set (Table 3).

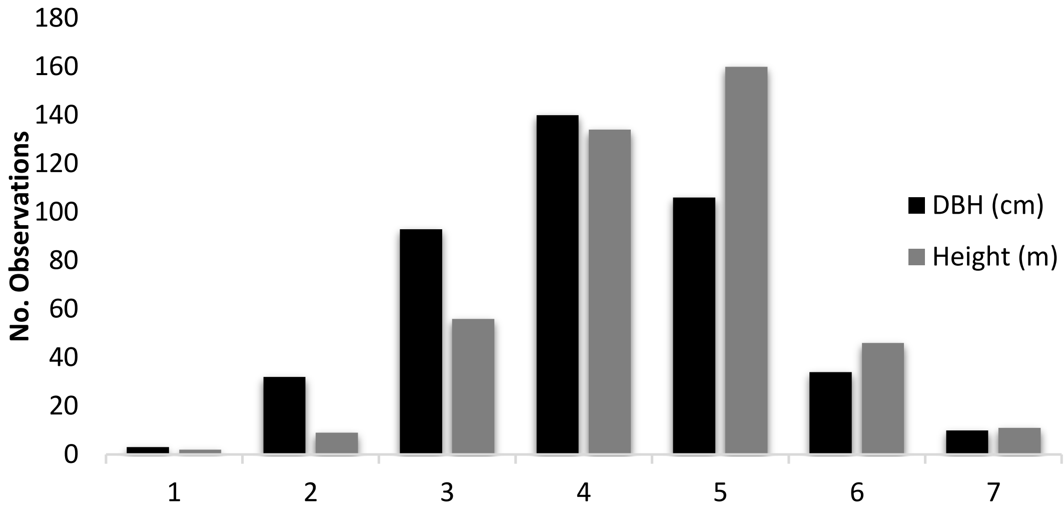
Table 1 Descriptive statistic and ANOVA of *A. malaccensis* plantation for one-hectare plot

		DBH (cm)			Height (m)		
Class	**N**	**Mean**	**Min**	**Max**	**Mean**	**Min**	**Max**
1	122	11.28±0.22	4.6	14.9	6.03±0.14	1.5	10.3
2	248	19.36±0.17	15.0	24.9	8.62±0.09	3.4	12.7
3	48	28.18±0.35	25.0	33.5	10.31±0.26	7.1	16.0
F Value		788.83**			185.39**		

DF = Degree of freedom, * = significant at $p < 0.05$, ** = significant at $p < 0.01$, ns = not significant at $p < 0.05$

Table 2 Summary of allometric equations derived from 10 destructive samples

Model	No of Eq.	Parameter	Equations	R^2 value	SE
$Mi = a(D)^b$	1	M of stem	$0.0717\ D^{1.9969}$	0.97	0.76
	2	M of branch-twigs	$0.064\ D^{2.7206}$	0.97	0.83
	3	M of leaf	$0.0287\ D^{1.9953}$	0.90	0.43
	4	Total AGB	$0.0856\ D^{2.2028}$	0.98	1.86



Column	1	2	3	4	5	6	7
DBH (cm)	< 5	5 to 10	10 to 15	15 to 20	21 to 25	25 to 30	31 >
Height (m)	< 2	2 to 4	4 to 6	6 to 8	8 to 10	10 to 12	12 >

Figure 1 Histogram of diameter at breast height (DBH) and height (H) from one-hectare plot in FRIM Research Station Maran

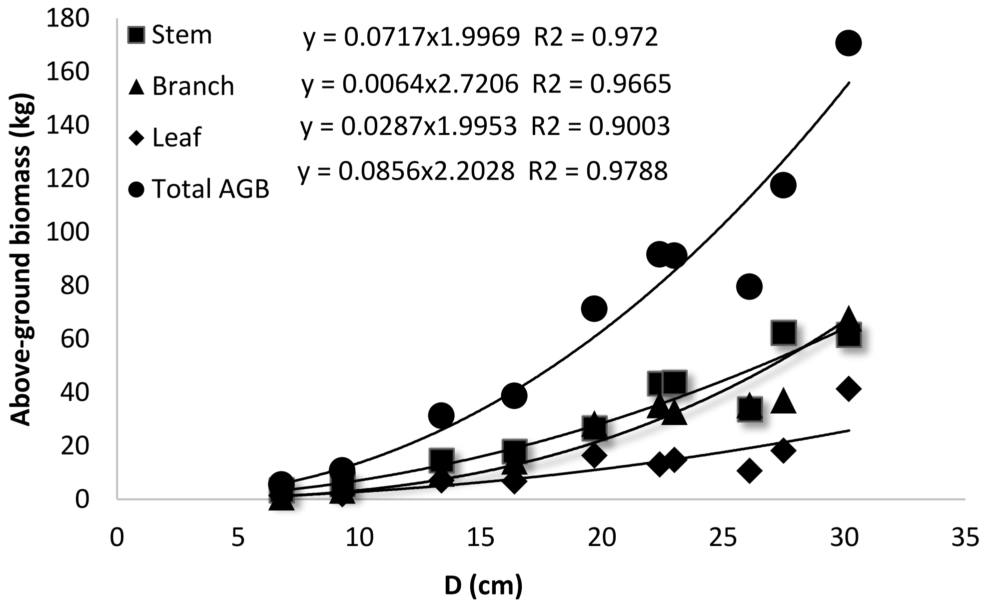


Figure 2 Regression models for allometric equation establishment for above-ground biomass using Diameter (D)

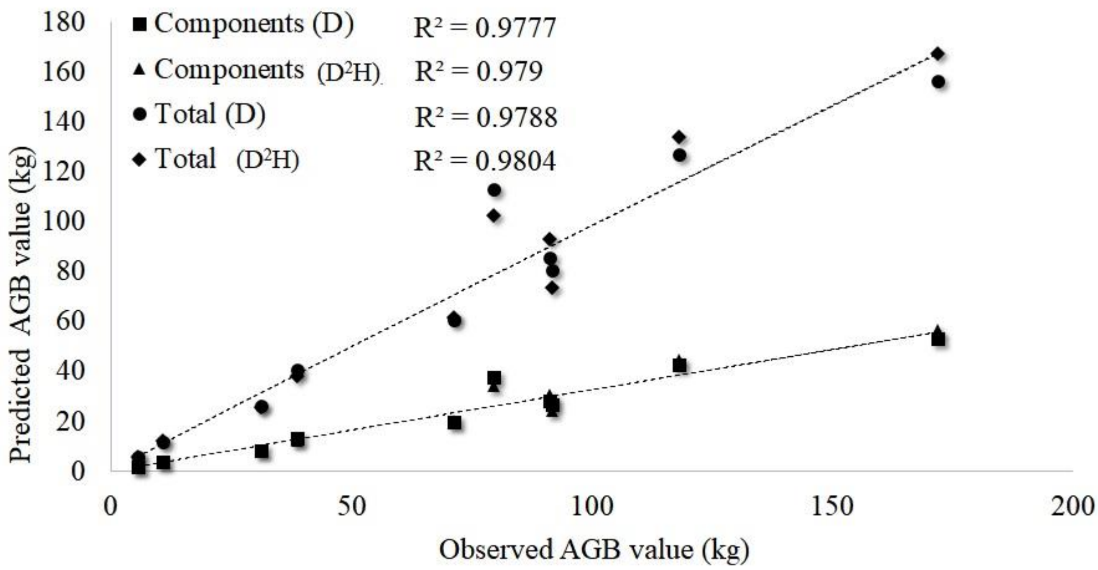


Figure 3 Above-ground biomass comparison between observation value and predicted value for equation using D and D^2H

Table 3 Comparison between predicted and observed value by developed allometric equation using sampling and large data set

Aboveground Biomass (Kg / 10 trees)				
Method	**Stem**	**Branch**	**Leaves**	**Total AGB**
Observed from field	311.9	264.4	131.0	707.3
Eq. model using D	308.8	274.7	123.0	706.7
Aboveground Biomass (Mg / ha)				
Method	**Stem**	**Branch**	**Leaves**	**Total AGB**
Eq. model using D	10.6	8.6	4.4	23.6

The relationship between diameter classes and tree components to aboveground biomass, carbon content, and carbon stocks was described by statistical analysis using ANOVA (Table 4). Carbon contents show slightly different among tree components from the observed samples (Table 5). The actual carbon content in stem, branch-twigs and leaves were 38.04, 39.59, and 43.42% representing 118.6, 104.7, and 56.9 kg respectively. Since there was not much difference between the carbon contents, the actual of each component has been calculated as average value; 4.1, 3.4, and 1.9 Mg ha^{-1} for stems, twigs, and leaves respectively. Considering the best fitting for total AGB from the allometric model (Eqn. (4)), the estimated AGC from this one-hectare plot was 9.4 Mg ha^{-1}. From the actual measurement of carbon storage, this monoculture plantation of *A. malaccensis* has sequestered 1046.4 kg CO_2 from ten sampling trees. Estimated about 34.5 Mg CO_2 has been sequestered from a one-hectare plot (Table 6).

Table 4 Results of ANOVA for the biomass, carbon percentage and carbon content (10 trees)

Source of Variation	DF	F-Values and Statistical Significance		
		Aboveground Biomass	Carbon content (%)	Carbon stocks
D	2	30.777**	2.101^{ns}	0.920^{ns}
TC	2	9.560**	32.218**	0.598^{ns}
DBH * TC	4	2.426^{ns}	1.782^{ns}	0.540^{ns}

DF = Degree of freedom, DBH = Diameter class, TC = Tree components, * = significant at p < 0.05, ** = significant at p < 0.01, ns = not significant at p > 0.05

Table 5 Observed and estimated biomass components, carbon density and carbon content

Tree Components	Observed			Estimated	
	AGB (kg)	AGC (kg)	AGC (%)	AGB ($Mg\ ha^{-1}$)	AGC ($Mg\ ha^{-1}$)
Stem (1)	311.9	118.6	38.04	10.6	4.1
Branch/twigs (2)	264.4	104.7	39.59	8.6	3.4
Leaf (3)	131	56.9	43.42	4.4	1.9
Total	707.3	285.4	40.35*	23.6	9.4

Note: * was an average of the carbon content of (1), (2), and (3)

Table 6 The average amount of above-ground biomass. Above-ground carbon and CO_2 sequestered in specific 10 years *A. malaccensis* plantation

Tree average amount	Observed trees (kg)	One hectare (Mg)
AGB	707.3	23.6
AGC	285.4	9.4
CO_2 Sequestered	1046.4	34.5

DISCUSSION

The stems and branches enclose the largest proportion of aboveground biomass (Komiyama et al. 2008). The plantation has more medium and large diameter classes, contributing more than 50% of AGB. It corresponds with the fact that the larger the stem diameter, the greater the biomass value (Manalu et al. 2016). Similar to previous studies, the result shows that the diameter at breast height is the best predictor (Chave et al. 2014). Several studies proposed some standard conversion factor of biomass to carbon is 50% or half of the biomass was composed biomass (Schroeder 1993). It is also supported by Houghton et al. (1995), which stated the conversion 50% of biomass turned to carbon. Another study found that the species wood density as a model variable considering 47% carbon contents in woody biomass (Hengeveld et al. 2015). We found that the value of carbon content gradually increased from the lower (stem: 38.04%) to the higher (leaf: 43.42%) in the component observed. Considering this plantation is still young, the stem and crown are in the development stage, the average value of 40.35% of carbon content measured reflects the actual value of carbon absorbed by *A. mallacensis* at the age of 10 years in this plantation forest. Therefore, the rate of CO_2 absorption (34.5 Mg ha^{-1}) in this *A. malaccensis* plantation also plays a significant role in reducing atmospheric CO_2 even at short rotation-aged.

CONCLUSION

This study showed that there is a significant contribution of different diameter classes to the aboveground biomass and carbon stock values. Over the past ten years, with three diameter classes represented in this plantation site, the information on aboveground biomass and carbon stocks obtained in this study can represent *Aquilaria's* productivity. Through allometric equations developed (Eqn. No.1, 2, 3 & 4), the amount of stem, branch-twigs, leaves, and total aboveground biomass respectively can be predicted using the diameter at breast height (DBH). The rate of carbon sink during the period of the trees being planted until it was ready to be harvested can be estimated with the average carbon content measured at 40.35%. This specific *A. malaccensis* plantation site has accumulated a significant amount of carbon for the past 10 years and more or less contributed in reducing atmospheric CO_2. The determination amount of carbon stocks that were presented in this plantation helps to mitigate global warming by capturing and storing carbon as well as enhancing natural sequestration.

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IMPACTS OF CARBON DIOXIDE RISE ON SELECTED MANGROVES SPECIES AT SG. HJ. DORANI FOREST RESERVE AND MATANG MANGROVE FOREST RESERVE

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Mangrove forests, also called mangrove swamps, mangrove thickets or mangals, naturally sequester carbon dioxide during photosynthesis. Several studies have shown that changes in CO_2 will affect plant physiological responses, stimulate photosynthesis, cause increased carbon uptake and assimilation. Thus, this study was conducted to measure the net rate of photosynthesis and respiration for selected mangrove species and to determine the effect of carbon dioxide (CO_2) concentration on selected mangrove species (*Rhizophora apiculata, Rhizophora mucronata*, *Avicennia alba* and *Avicennia officinalis*) at Sg. Hj. Dorani Forest Reserve (FR) and Matang Mangrove FR. Particularly, the rate of photosynthesis was seen to increase with the increase in CO_2 concentration for the four study species in both Sg. Hj. Dorani FR and Matang Mangrove FR. The rate of photosynthesis is also seen to be low at night for species being studied. CO_2 concentrations have a significant effect on the rate of photosynthesis for these species depending on different times where $p<0.05$ at Sg. Hj. Dorani FR except for *Avicennia officinalis* whilst in Matang Mangrove FR, CO_2 concentrations only affect the rate of photosynthesis of *Rhizopora apiculata* and *Avicennia officinalis* with $p<0.05$. *Rhizopora apiculata* can respond better to changes in CO_2 concentration either in the morning or evening or in either the high tide or low tide condition. These findings are based on short-term observations; therefore, it is recommended that similar studies be conducted in the long term and include more variables to understand the mangrove ecosystem and its role in assessing and monitoring the impact of climate change.

Keywords: Elevated CO_2 concentration, photosynthesis, climate change, coastal wetlands

INTRODUCTION

Mangrove forests are referred to as one of the various habitats and natural coastal environments other than muddy areas, sandy substrates, rocky beaches, mangrove forests, submerged aquatic plants and coral reefs - providing food, shelter and breeding grounds for terrestrial species (Nagelkerken et al. 2008). Some studies have shown that changes in CO_2 will affect the physiological responses of plants, stimulate photosynthesis, and lead to increased carbon uptake and assimilation, to the point of increasing growth-data to support the study is still lacking, especially for forest species.

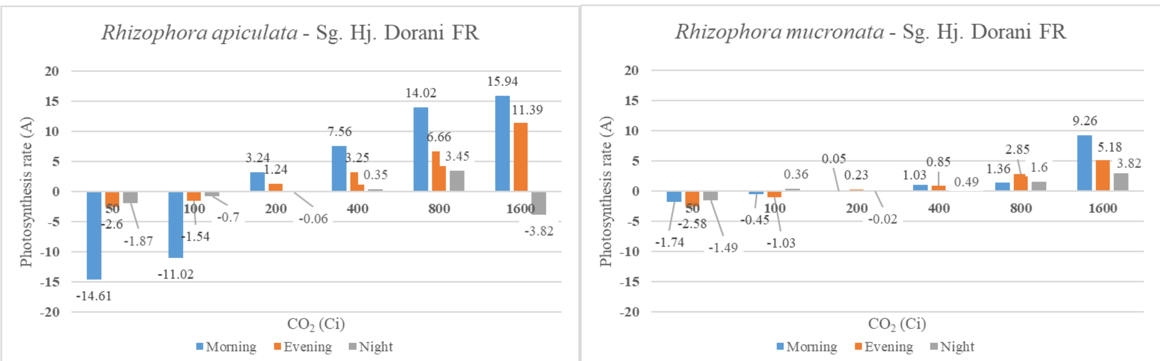
It is important to be able to measure the level of environmental stress in mangrove plants - physiologically, the mangrove species is a stress-resistant species (Ahmad 2006). Thus, this study was carried out to measure the net rate of photosynthesis and respiration for selected mangrove species and to determine the effect of carbon dioxide (CO_2) concentration on selected mangrove species (*Rhizophora apiculata, Rhizophora mucronata*, *Avicennia alba* and *Avicennia officinalis*) at Sg. Hj. Dorani Forest Reserve (FR) and Matang Mangrove FR.

MATERIALS AND METHODS

The study areas are located at Sg. Hj. Dorani Forest Reserve (FR) and Matang Mangrove FR. The mangrove forest of Matang covers an area of 40 711 ha, along a 52 km stretch of the northern coast of Perak. Managed by the Forestry Department of Perak, it is the single largest mangrove forest reserve in Peninsular Malaysia, accounting for 40% of the total mangrove forest in the peninsula. Sg. Hj. Dorani is located 90 km to the north of Kuala Lumpur, near Sabak Bernam, on the west coast of Peninsular Malaysia. It is nearly 2.6 km long and has a 1:100 foreshore slope. Bernam River and Perak River both carry a huge number of sediments to the Malacca Strait (Cleary & Goh 2000), meeting the coastline some 40 km away from Sg. Hj. Dorani. Littoral currents distribute this fluvial discharge over the shoreline to the Sg. Hj. Dorani beach where destruction of the coastal forest decreases the chance of sediment deposition. For each study site, four species were selected (*Rhizophora apiculata, Rhizophora mucronata*, *Avicennia alba* and *Avicennia officinalis*) with three replicates for each species that make 24 trees being tagged. The CO_2 concentration was elevated at 50 ppm, 100 ppm, 200 ppm, 400 ppm, 600 ppm, 800 ppm and 1600 ppm and their photosynthesis rate was measured using LICOR 6400. The reading was taken three times a day, in the morning, evening and night for each replicate.

RESULTS AND DISCUSSION

All four species in both study areas showed a higher rate of photosynthesis with an increase in CO_2 concentration in the morning and evening (presence of light), however, the trend was seen to be different at night. The rate of photosynthesis for *R. apiculata* is higher than *R. mucronata* for both study areas. The photosynthesis rate of *A. officinalis* with CO_2 enrichment was higher in the evening; on the other hand, *A. alba* was higher in the morning and the evening (Figure 1).



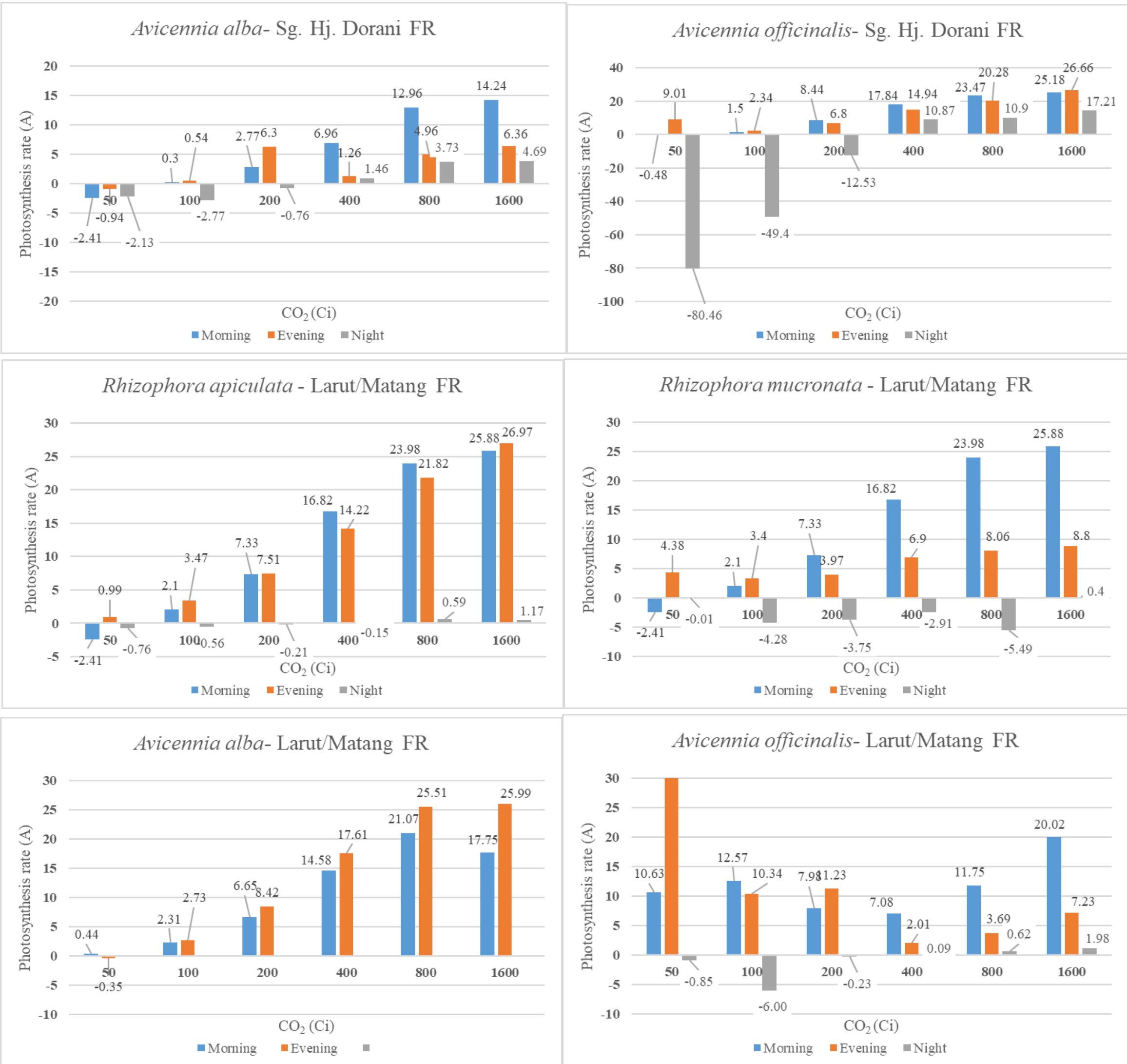


Figure 1 Photosynthesis rate of selected species at Sg. Hj. Dorani Forest Reserve and Matang Mangrove Forest Reserve

The test results of the relationship between time difference and CO_2 concentration on the rate of photosynthesis of each study species in Hj. Dorani FR. The time factor in the morning, evening and night showed a significant difference of P <0.05 for the species of *R. apiculata, A. officinalis* and *A. alba*. This means that time has a significant effect on the rate of photosynthesis of these species. However, for *R. mucronata*, time did not affect its photosynthesis rate statistically when tests showed no significant difference i.e., P> 0.05.

The CO_2 concentration factor showed a significant difference of P <0.05 for the species of *R. apiculata*, *R. mucronata, A. officinalis* and *A. alba*. This means that different CO_2 concentrations have a significant effect on the rate of photosynthesis of these species.

The interaction between time and CO_2 concentration also showed significant differences (P <0.05) for the species of *R. apiculata*, *R. mucronata* and *A. alba*. It means that CO_2 concentrations have a significant effect on the rate of photosynthesis of these species depending on different times; but not for *A. officinalis* where P> 0.05.

The test results of the relationship between time and CO_2 concentration on the rate of photosynthesis of each study species in Matang Mangrove FR showed that the time factor of the morning, evening and night showed a significant difference of $P < 0.05$ for the four species *R. apiculata*, *R. mucronata*, *A. officinalis* and *A. alba*. This means that time has a significant effect on the rate of photosynthesis of these species.

The CO_2 concentration factor showed a significant difference of $P < 0.05$ for *R. apiculata* and *A. officinalis*. This means that different CO_2 concentrations have a significant effect on the rate of photosynthesis of these species. In contrast, CO_2 concentrations did not provide a statistically significant effect ($P > 0.05$) on the rate of photosynthesis for *R. mucronata* and *A. alba*.

The interaction between time and CO_2 concentration also showed significant differences ($P < 0.05$) for *R. apiculata* and *A. alba* species. This suggests that CO_2 concentrations have a significant effect on the rate of photosynthesis of these species depending on different times. But not for *R. mucronata* and *A. alba* where $P > 0.05$.

As a discussion, the rates of photosynthesis for all study species were low at night. It is because photosynthesis does not occur at night for most plants due to the process of photosynthesis carried out by plants require sunlight. The concentration of carbon dioxide is also influenced by the rate of photosynthesis of the mangrove species studied. It is also evidenced by previous studies looking at interactions between plant photosynthesis with environmental factors (Long 1991; McMurtrie & Wang 1993; Teskey 1997; Ziska & Bunce 1997a, b; Saxe et al. 2001, Turnbull et al. 2002).

CONCLUSION

Rhizophora apiculata is able to respond to changes in the concentration of CO_2 than to *R. mucronata* especially in the morning or in the afternoon. It is important to know the appropriate rate of stomata opening for the exchange of CO_2 (food manufacturing and tree growth). The efficiency of photosynthesis/respiration depends on light/temperature. These data are important to understand physiological processes in mangrove forests which have not been well explored in Malaysia. These findings are based on short-term observations; therefore, it is recommended that similar studies be conducted in the long term and incorporate more modifiers to understand the mangrove ecosystem and its role in assessing and monitoring the impacts of climate change.

ACKNOWLEDGEMENT

We thank the staff of the Climate Change and Forestry Program and Ecohydrology Program for their assistance with chamber measurements, and tree surveys and for conducting field works. We would also like to thank the Technical Committee for Research and Development of the program of planting mangrove trees and other suitable species along the country's coastline in supported us using their fund.

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ASSESSMENT OF CLIMATE CHANGE IMPACTS ON TROPICAL FOREST ECOSYSTEM AND FORMATION OF APPROPRIATE ADAPTATION STRATEGIES: TekamFACE SYSTEM

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Forestry is the second most important sector in the discussion of global climate change issues. This sector is hotly debated as it is often associated with greenhouse gas emissions through logging activities. Given the importance of the forestry sector to our economy, it is appropriate that we understand more deeply the impact of climate change on the country's forest resources. Assessment of Climate Change Impacts on Tropical Forest Ecosystem was done to study the changes to forest ecosystem and productivity in the production forest with elevated CO_2 levels through TEKAM Free-Air Carbon Dioxide Enrichment (TekamFACE) system. TekamFACE system was built to release additional CO_2 into the air, elevating atmospheric CO_2 from 410- 450 ppm (ambience) to 600 ppm and above (elevated). This is done in the production forest and allows long term study in a natural environment. Appropriate adaptation strategies will then be planned if introduced species are needed to be planted for sustainable forest management. The adaptation steps of the forestry sector toward climate change are to be included in the National Report and for the use of the Malaysian Adaptation Plan in preparing the United Nations Framework Convention on Climate Change (UNFCCC) report. Climate change will affect the forest ecosystem, growth and productivity and hence sustainable forest management principles are necessary.

Keywords: CO_2 enrichment, species adaptation, tropical production forest

INTRODUCTION

Climate change has been observed since 1950 with exponential anthropogenic carbon dioxide (CO_2) emission for at least the past 50 years (Hofmann 2008). The CO_2 concentrations can reach up to 936 ppm (RCP*8.5) by the year 2100 as predicted by Intergovernmental Panel on Climate Change (IPCC) (IPCC, 2013). A study through computer modelling projections by Azian et al. (2018) showed an increase in productivity of tropical rainforests especially in Malaysia by 13% or 12.8 GgC ha-1 with an increase in CO_2 and temperature under the Representative Concentration Pathway (RCP) 8.5

scenario, and a decrease in forest productivity of 7% or 8 GgC ha-1 with an increase in temperature only in under the RCP 8.5 C90 scenario by 2099.

As a starting point to support the preparation process and construction of the National Adaptation Plan (NAP), the Government of Malaysia has allocated funds in the Eleventh Malaysia Plan to the Forest Research Institute Malaysia (FRIM) to conduct a study entitled "Climate Change Assessment of Ecosystems Forests and the Establishment of Appropriate Adaptation Strategies". This research was conducted for five years from 2016 to 2020 through a memorandum of agreement (MoA) between FRIM and UKM on 12 April 2016. The objective of the MoA was particularly on the establishment of the TekamFACE system that consists of the control house and a structure of hexagon to release the elevated CO_2 gases within a budget of RM525,000.00. This system is designed to enable the study of the response of forest vegetation species to an increase in CO_2 gases by creating the facilities with an experimental space that can produce environmental conditions with an increase in the concentration of CO_2 gas.

MATERIALS AND METHODS

The construction of the TekamFACE system in the form of a control house and a structure of a hexagon as high as 12 m and a 6 m side has been implemented in the Compartment 84, Tekam Forest Reserve, Jerantut, Pahang. It releases additional CO_2 into the air, elevating atmospheric CO_2 from 500 ppm to 600 ppm and above (elevated) (Azian et al. 2020). This is done to allow long term study of the assessment of climate change impacts on tropical forest ecosystems in a natural environment.

RESULTS & DISCUSSION

TekamFACE system (Figure 1) was successfully operated in 2018 that needs to be integrated with the control panel house and the data observation computer so that it can generate accurate field data. Generally, the operation of this TekamFACE system begins with the production of CO_2 gas from the gas tank at the control house, followed by the release of the CO_2 gas through the flow pipe into the airspace within the FACE hexagon. Then, as shown in Figure2, data is transmitted from the 4 in 1 sensor via LAN/Wifi, stored in the computer using EZ ICMS software, and monitored using an Android phone. 4 in 1 sensor have been installed in the Tekam Forest Reserve plot, Jerantut, Pahang to measure the air of the forest environment. Among the parameters measured are (1) CO_2 (ppm), (2) Air humidity (% RH), (3) Light intensity (Lux) and (4) Temperature (°C) with a frequency every 10 min for 24 hours/day. Generally, the normal forest environment shows the average monthly range of CO_2 is 495 ppm, temperature at 26.9 ° C, humidity at 84.2% and light intensity at 110 Lux. Starting June 2018, the increase in CO_2 gas in the normal environment is ± 125 ppm within the FACE hexagon range. Meanwhile, the operating manual of the TekamFACE system has been published in 2018 and received the award of the best manual published during FRIM Awards Day 2019 (Figure 3). The manual was then upgraded in January 2021 with additional troubleshooting steps to be taken when the system is not functioning well. Furthermore, this system was awarded in The Malaysia Book of

Record as the first "Free Air CO_2 Enrichment (FACE) System Developed in a Tropical Production Forest" (Figure 4).

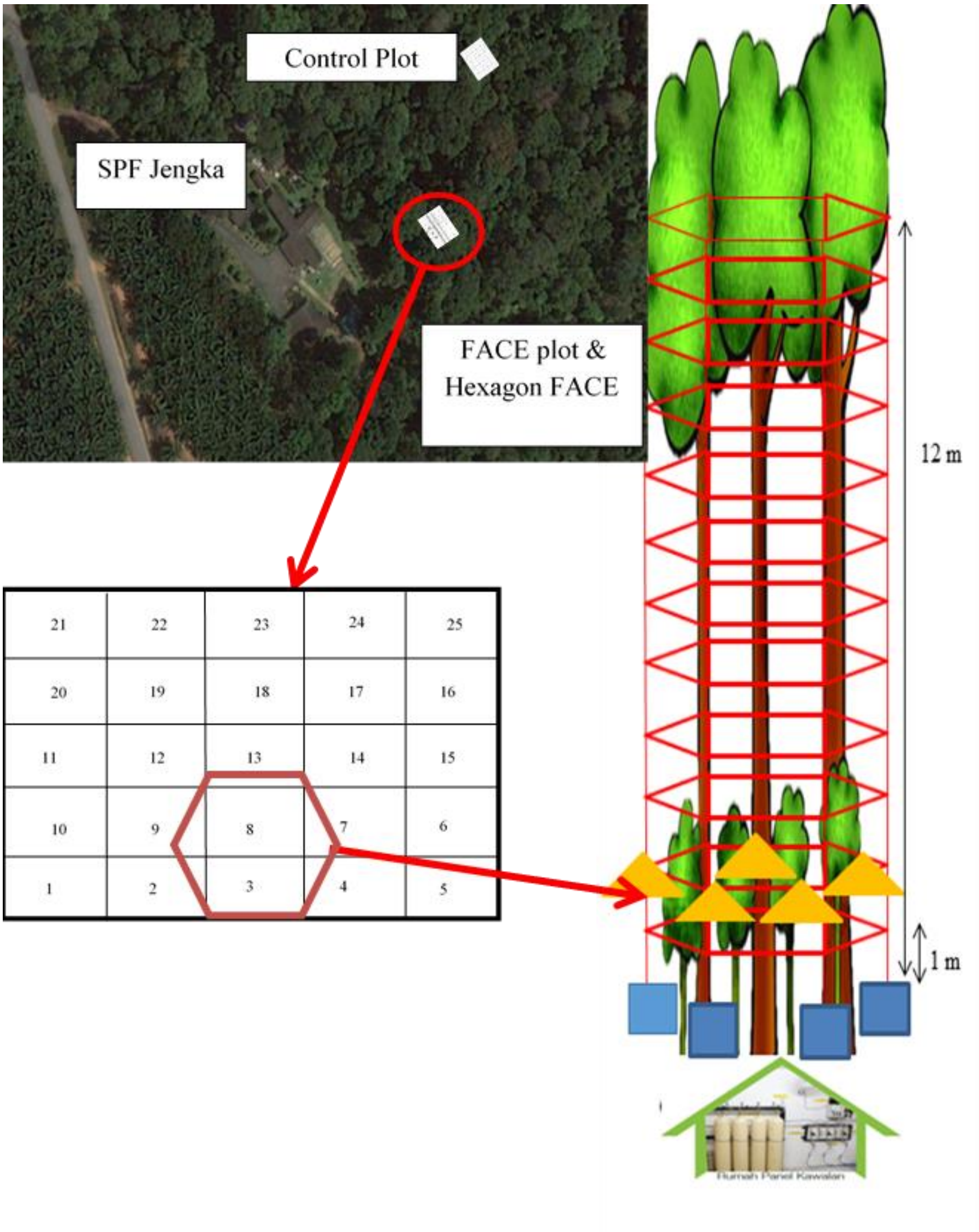

Figure 1 Position of FACE compartment and control compartment (top left), FACE hexagon position position inside FACE compartment (bottom left) as well as an illustration of FACE FRIM system (right) in Compartment 84, Tekam Forest Reserve, Jerantut, Pahang

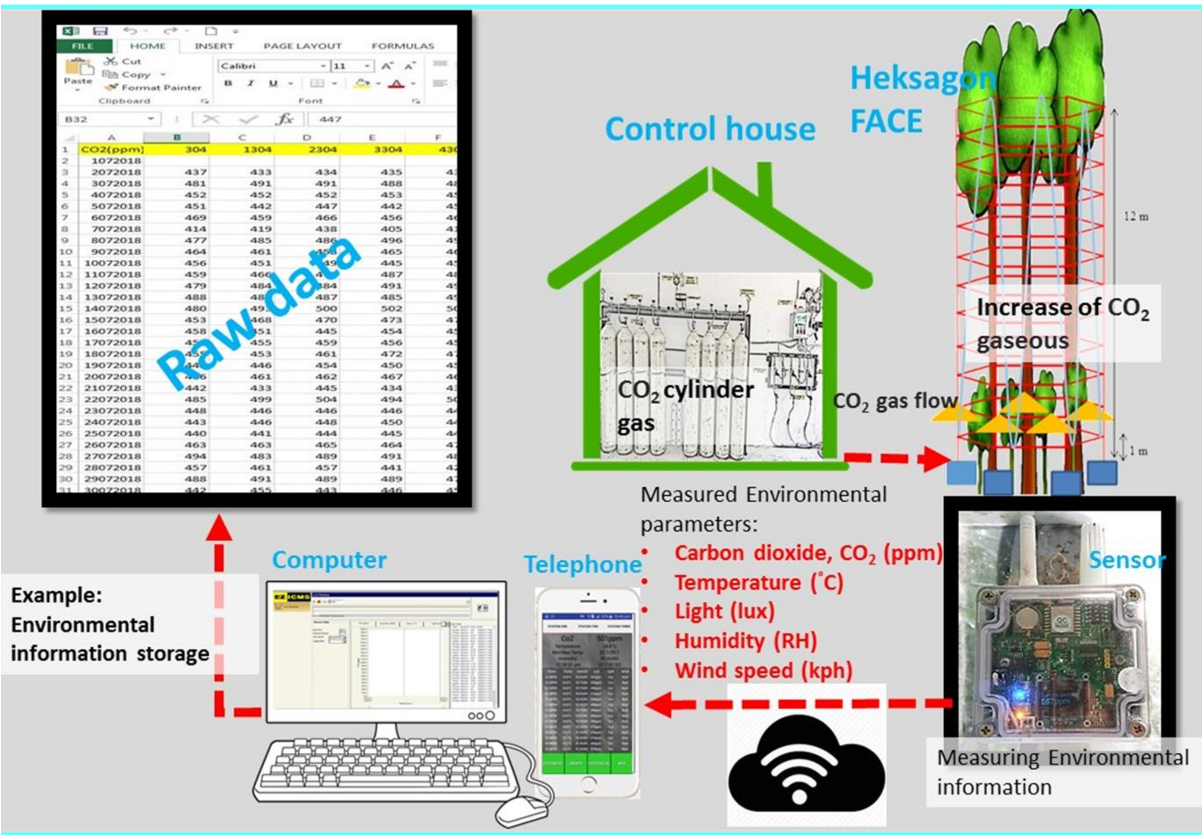

Figure 2 TekamFACE system flow chart starts from CO_2 gas addition to environmental data collection via LAN/Wifi

Figure 3 The manuals of the TekamFACE system published

Figure 4 The Malaysia Book of Record as the first "Free Air CO_2 Enrichment (FACE) System Developed in a Tropical Production Forest" certificate

CONCLUSION

The MoA between FRIM and UKM has successfully established the TekamFACE system. The operation of the system is continued in the Twelve Malaysia Plan project. The study of the impacts of elevated CO_2 on forest ecosystem and productivity was conducted with the main research on vegetation structure, floristic composition, and growth characteristics, as well as focused studies, including microbes, physiology, soil, phenology, fauna, seeds, DNA and lichen. The final result will signify the impacts on the forest ecosystem and forest productivity of commercial timber and non-timber products over time and the appropriate adaptation strategies will be determined.

ACKNOWLEDGEMENT

We would like to thank Universiti Kebangsaan Malaysia (UKM) for their assistance and collaboration in establishing of FACE structure and system. We also appreciate the staff of the Climate Change and Forestry Program (CCF), Mr. Ridzuwan Mamat from the Geoinformation Program and Jengka Research Station in their work to make sure everything about FACE and the system could run smoothly. We also thank Jerantut Forestry District Office, Pahang State Forestry Department and Forestry Department Peninsular Malaysia for their help and support to make sure our dream of conducting research on adaptation through the forest ecosystem becomes reality. Finally, we would like to give our appreciation to the Ministry of Energy and Natural Resources (KeTSA) for funding this system through the Forest Research Institute Malaysia (FRIM).

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ASSESSMENT OF SOIL MOISTURE AND VEGETATION INDEX IN PASOH FOREST RESERVE FOR PLANT SENSITIVITY CHARACTERISATION

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Dryness is a threat to our forest ecosystem due to climate change, especially in a dry zone. The forest ecosystem interacts differently with environmental changes and dryness. Specific parameter related to dry forest environment needs the integrated field observation and remotely-sensed data for better assessment. There are various techniques that are effective for deriving environmental parameters such as spectral indices based on remote sensing data. Pursuant to that, this study was aimed to develop spectral indices for estimating vegetation and soil water content based on satellite remote sensing for dry land of Pasoh Forest Reserve (PFR). We applied the remote sensing technique which relies on the use of the soil moisture index (SMI) which uses the data obtained from satellite sensors in its algorithm. The Normalized Difference Vegetation Index (NDVI) and SMI are suitable and used for this purpose. Near-infrared, red, and blue bands were applied for vegetation and soil moisture index estimation. Based on Piecewise Linear Regression Model, NDVI and SMI are closely correlated at $r^2=0.5408$ (access tube no. 1-21) and $r^2=0.6593$ (access tube no. 22- 39), suggesting that this index is positively responding and strongly correlated with Near Infra-Red (NIR) reflectance.

Keywords: Vegetation index, soil moisture index, remote sensing, tropical forest, climate change

INTRODUCTION

A severe dry period in 2019 and 2020 was forecasted in Malaysia. Thus, it is critically important to understand specific forest ecosystem functions affected by prolonged dry conditions. Soil water status from the field and remotely sensed techniques could be used to represent the exchange processes of energy and water between the terrestrial ecosystem and the atmosphere as a core of our environmental science. Assessment of the impact of soil water on forest ecosystem should be conducted because the quantity of water present in the soil will influence many processes including gas exchange, diffusion of nutrients to plants root and forest health in general. This study is conducted to strengthen knowledge on the effect of dry conditions on the forest ecosystem. Thus, by carrying out this study, new fundamental data on vegetation, soil water content and evapotranspiration for tropical rainforest can be added by using spectral indices based on high-resolution satellite remote sensing images. Therefore, the objective of the study is to develop spectral indices for estimating vegetation and soil water content based on satellite remote sensing for dry land of Pasoh Forest Reserve (PFR).

MATERIALS AND METHODS

Background of the Study Area

The PFR experience extreme and prolonged dryness during the El Niño Southern Oscillation (ENSO) events (Marryanna et al. 2017a). Thus, the site is suitable for assessing the response of soil moisture during extremely dry periods. The PFR is a lowland dipterocarp forest with a canopy height of 30–40 m (with emergent trees ~ 45 m tall) located in Negeri Sembilan, Malaysia at 2° 98' N, 102° 31' E, at approximately 75 to 150 m above sea level (Figure 1).

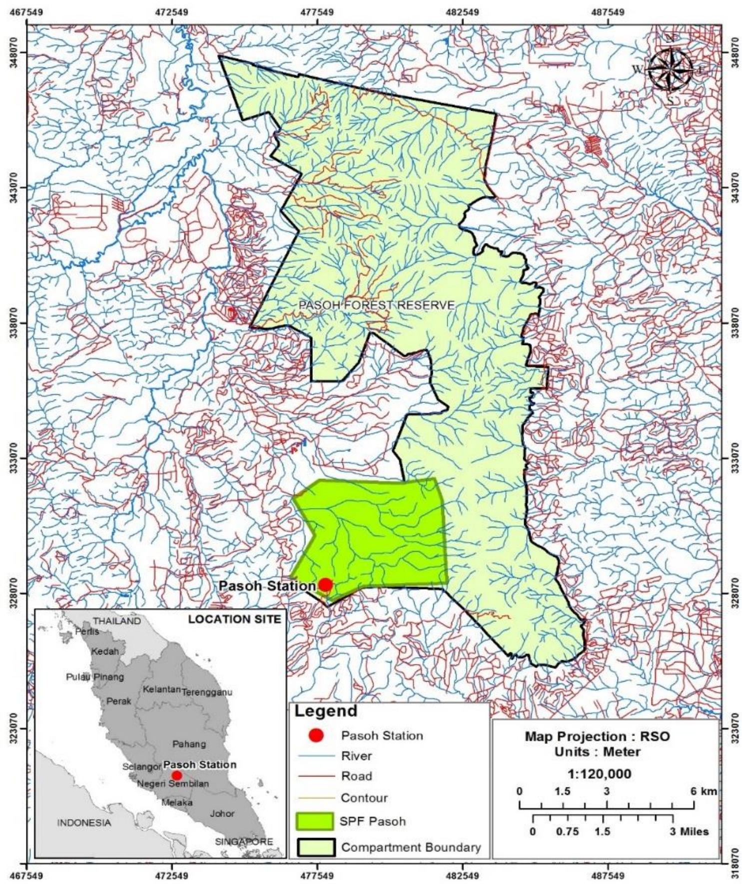

Figure 1 The location of the PFR in Peninsular Malaysia and the Pasoh Research Station

The mean annual rainfall at the study site is 1800 (± 285) mm recorded between 1996–2015 (Marryanna et al. 2017b; Marryanna et al. 2019), peaking from March to May and from October to December (Kosugi et al. 2008). The study area is located within a dry zone of Peninsular Malaysia and receives the lowest annual rainfall among adjacent south-eastern tropical rainforests (Noguchi et al. 2003, 2016; Marryanna et al. 2017b, 2019). Recent precipitation was provided from June 2015 to May 2016 for an overall description of the recent meteorological condition of the site (Figure 2).

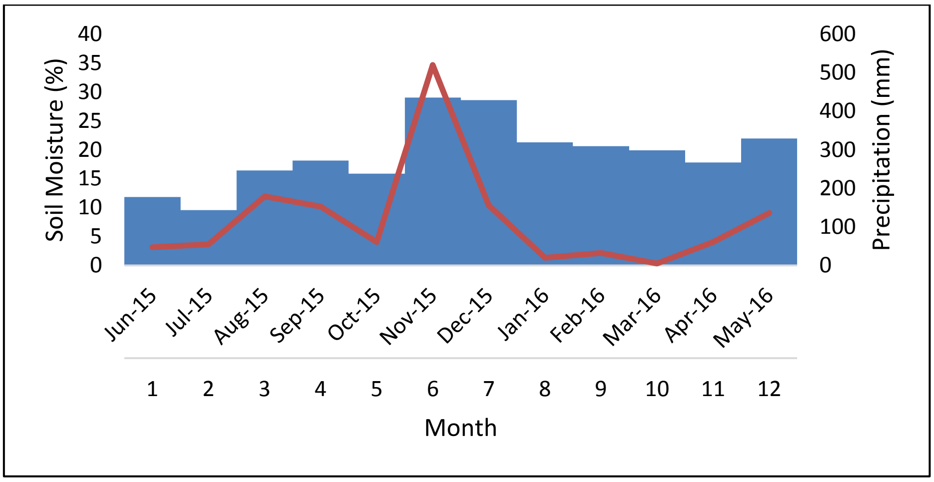

Figure 2 Precipitation and soil moisture from June 2015 to May 2016

Satellite Image Data Acquisition and Indices Derivation

A high-resolution of Worldview-2 satellite image with 8 multispectral bands dated November 7th of 2019 was retrieved. The image provided large spectral bands of four standards colours: red, blue, green, near-infrared-1) and four new colours of red-edge, costal, yellow and near-infrared-2, sensing at 1.84 meters multispectral resolution. Based on these bands, near-infrared (NIR), red, and blue bands indices were calculated as below:

The NDVI was calculated as:

NDVI = (NIR – red) / (NIR + red)   [1] (Rouse et al. 1973)

The SMI was calculated as:

SMI = NIR / Visible Blue   [2] (Dupigny-Giroux & Lewis 1999)

Healthy vegetation absorbs most of the visible light that hits the vegetation cover and reflects a large portion of the near-infrared light. Unhealthy or sparse vegetation reflects more visible light and less near-infrared light. Theoretically, NDVI is ranging from -1.0 to +1.0, whereas dense green vegetation could be valued approximately 0.6 – 0.9; sparse vegetation such as shrubs or grassland usually have values within 0.2 – 0.5 meanwhile negative values indicate the clouds, water area, barren rock, snow and bare sand areas (Tucker 1980). Thus, a small index value of NDVI corresponds to having minimal evapotranspiration that represents bare ground or little vegetation.

Soil Moisture Sampling

Field observation of soil moisture data from the study site was obtained from the 39 soil moisture access tubes described as ground points in this study. The soil moisture was obtained from six depths from 10, 20, 30, 40, 60 and 100 cm using the PR2 Soil moisture sensor. The NDVI and SMI indices were then extracted based on the 39 tubes data for further analysis. The study employed the Spatial Analyst tool for the extraction of the access tubes points. Furthermore, Piecewise Linear Regression Model was used for correlation analysis of the soil moisture data and remote sensing indices. A map for the indices was developed to characterize vegetation vigour and soil moisture availability in the study site.

RESULTS

Normalized Difference Vegetation Index (NDVI) and Soil Moisture Index (SMI)

The calculated indices of NDVI for the PFR where, the soil moisture access tubes were located show that, area at the observation tower mostly has a high NDVI value as presented with the green colour. High indices value presented by greenish to yellowish (Figure 3). The NDVI range was 0.3 – 0.8 approaching a value of +1.00 signifying healthy vegetation of the study site. Though the lowest value was 0.3, the site was assessed as entirely covered by a canopy. The lowest NDVI value suggested was due to natural canopy opening by wind through even. The SMI range was 2 – 4 and more area was covered by moderate to low index value. The soil moisture is often related to soil physical properties, which are described with soil water retention curve. The relationship between capillary pressure and soil water content depends on the soil pore size distribution (Kosugi 1997).

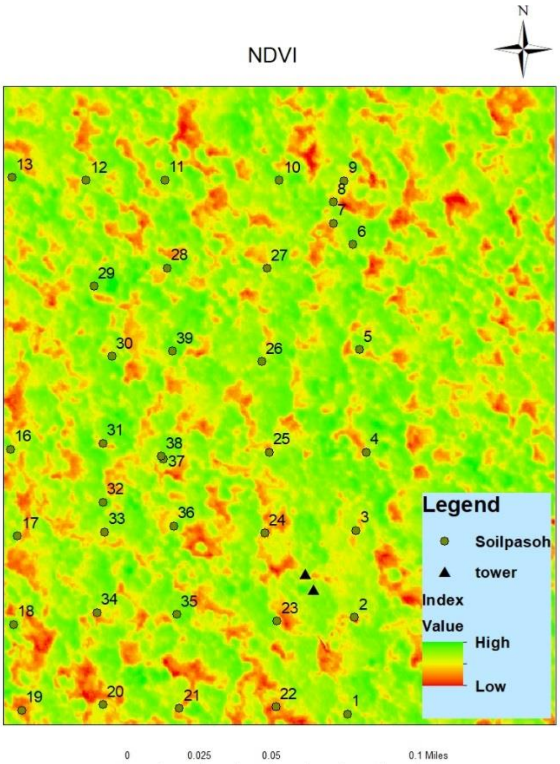

Figure 3 NDVI map indicates low to high index values for the site within the ground points

NVDI and SMI Correlation Analysis

The relationship between the NDVI and SMI index is depicted in Figure 5. Based on Piecewise Linear Regression Model, NDVI and SMI are closely correlated at r^2=0.5408 (access tube no. 1-21) and r^2=0.6593 (access tube no. 22- 39), suggesting that this index is positively responding and strongly correlated with Near Infra-Red (NIR) reflectance.

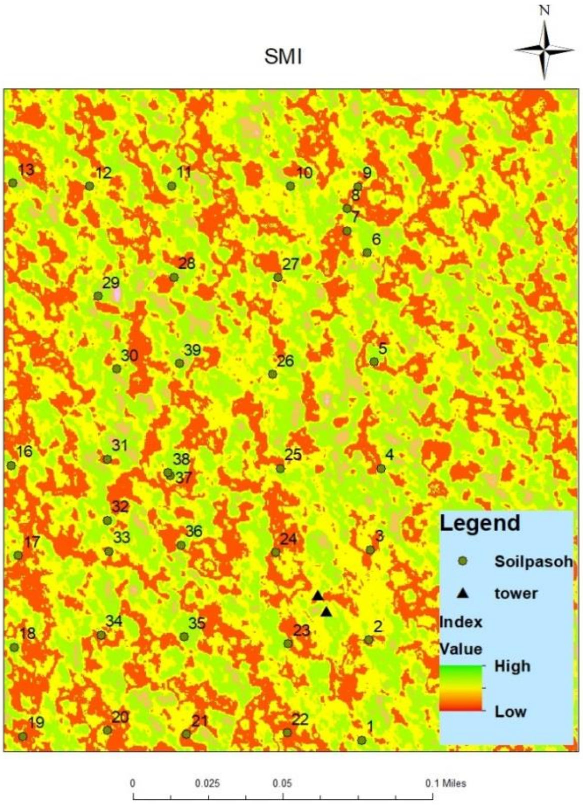

Figure 4 MI map indicates index values for interpreting soil moisture conditions for the study area

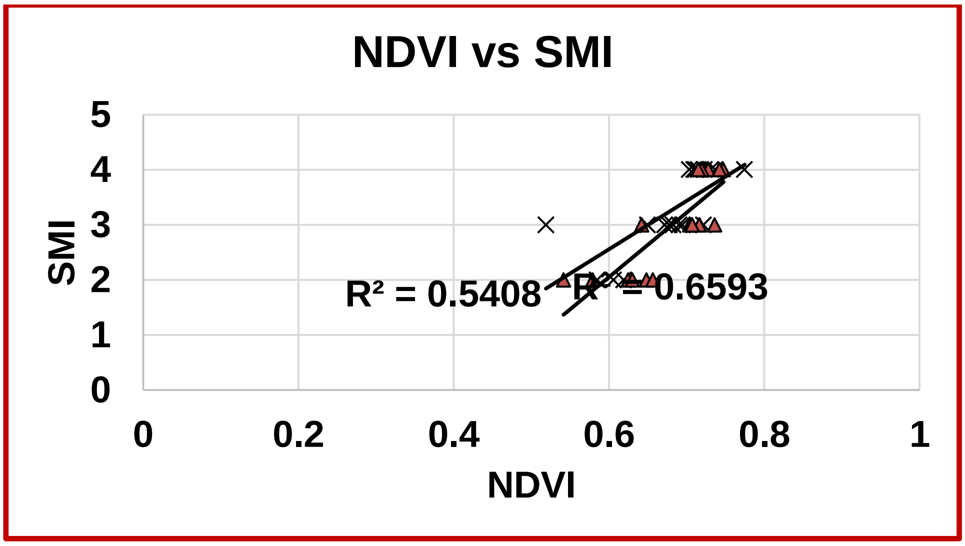

Figure 5 The relationship between NDVI and SMI for PFR

DISCUSSION

The impact of the dry seasons can be estimated based on satellite images therefore, the study chose NDVI to develop a characterization of forest area as a key indicator for vegetation vigour and dryness assessment. The NDVI shows a good agreement with other studies conducted in dry tropical regions during the wet season. However, a study conducted in PFR in September 2000 during the wet season was much higher (Sheriza et al. 2015). This is particularly true because the satellite image was derived during the month of November 2019, which was the wet season, therefore reporting a high value of the NDVI index. This suggests that dryness monitoring is possible particularly during the dry season. This is because severe drought can sometimes occur during the wet season of March–April 2005 which was found in a similar study conducted in PFR. The SMI index shows an agreement with NDVI since the relationship is significant. Therefore, these indices serve as a better tool for monitoring drought than any individual index alone.

CONCLUSION

Satellite remote sensing is a vital tool for the characterization of dry tropical forests. Due to limited studies conducted in the dry forest in Peninsular Malaysia, forest managers did not have access to up-to-date data. This research will aid the forest department to develop management planning to secure forested land for sustaining forest ecosystem services.

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WATER FOR LIFE PROJECT (PHASE III): 2020-2021 AT PEAT SWAMP FOREST, AYER HITAM (NORTH) FOREST RESERVE, JOHOR

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Peat swamp forest characteristics like a sponge, which can absorb a lot of water. The Ayer Hitam (North) Forest Reserve (AHNFR) is one of the remaining contiguous areas of peat swamp forest located in Muar district, Johor state, Malaysia. AHNFR has been gazetted as Permanent Forest Reserve in the provision of National Forestry Act 1984 on 28th February 1940 (Gazette No. 272) and its total areas are stated as 3,797 hectares (ha). Apart from that, AHNFR is the only peat swamp forest recognised as Forest State Park in Peninsular Malaysia. AHNFR is best described as the last 'black jewel' forest remaining in the state of Johor as other peat swamp forest areas have perished. AHFR is surrounded by three (3) river systems: the Muar River in the northwest, the Sarang Buaya River in the south and the Batu Pahat River in the southeast. Oil palm plantation surrounded the forest reserve and water resource is constantly flows from the forest reserve through the drainage system. For this project, FRIM is collaborating with Yayasan Kemanusiaan Muslim Aid Malaysia (YKMAM) through a research fund from Coca-Cola Malaysia. This collaborative project aimed at the rehabilitation of degraded peat swamp forest areas through reforestation and maintaining the water table through the construction of a small check dam in the AHNRF area. Observation on ground water level has shown that the increment of water level in 2020 was higher than in 2019 after redesigning of the check dam from rectangular to V-notch shape. Indirectly, it also means that more water has been retained in the forest reserve. Based on a net water level increment of 18.4 cm, 1.689 billion litres of water had been replenished with reference to the head water catchment of Batu Pahat River in 2020. In terms of flow rate, it was reduced from 0.252 m^3/sec to 0.1057 m^3/sec. Based on the difference between flow rates, the rough amount of water replenishes calculation of 4.61 billion litres, or 0.005 billion litres/ha/year retained in AHNFR for 2020.

Keywords: Peat swamp forest, rehabilitation, water level

INTRODUCTION

The Water for Life Project Phase II (2016-2017) is a collaboration project with Yayasan Kemanusiaan Muslim Aid Malaysia (YKMAM) supported by a Coca-Cola Malaysia research fund. The project is located at Ayer Hitam North Forest Reserve (AHNFR) in Muar, Johor (Figure 1). AHNFR has been gazetted as a Permanent Forest Reserve in the provision of the National Forestry Act 1984 on 28th February 1940 (Gazette No. 272) and its total areas are stated as 3,797 hectares (ha). The surrounding areas of the forest reserve are dominated by the oil palm plantation and a drainage system is necessary for plantation management (Shamsuddin et al. 2021). However, the outflow from the drains affects the water table in the forest reserve. Hence, the forest is easily caught by fires during the dry season. The outflow from the forest reserve must be controlled to maintain the water table. The forest surface will get dryer as the water table drops. To prevent subsidence and fire occurred in peat swamp forest areas, groundwater levels should be maintained between 40 cm below and 100 cm above the peat surface (Wosten et al. 2008).

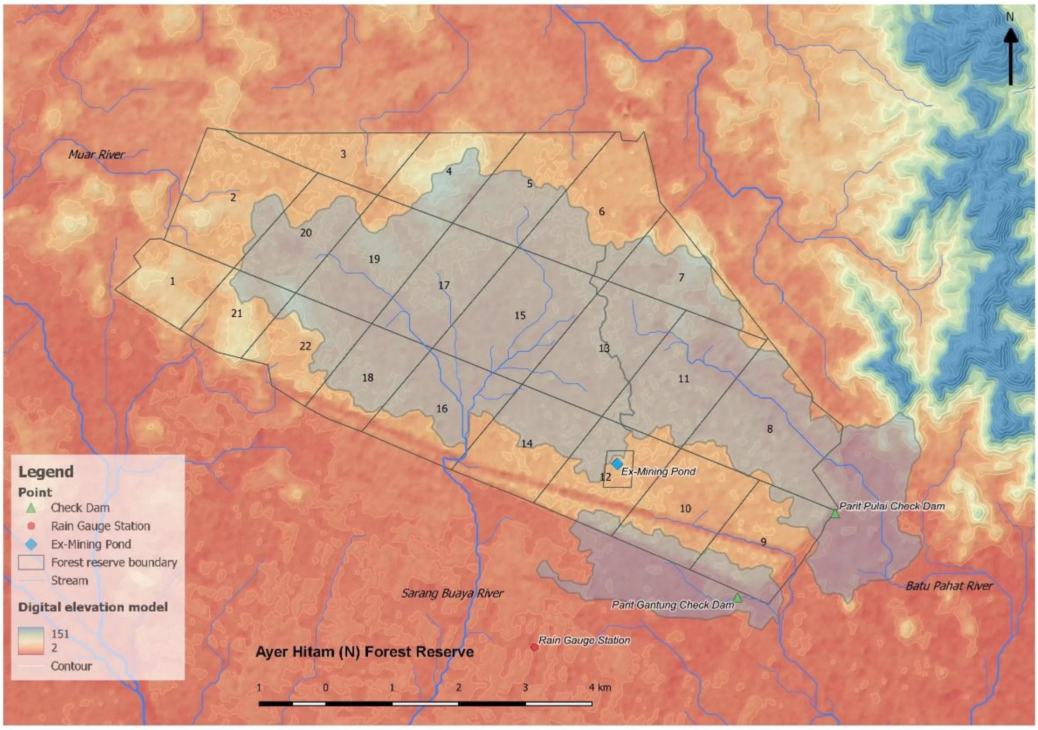

Figure 1 Map of Ayer Hitam Forest Reserve North, Muar, Johor

The first phase of the project ran from 2015 to 2016. While the second phase of the project ran from 2016 to 2017 focused on the rehabilitation of the degraded peat swamp forest areas and conservation of the water table through the construction of water block structure. The objectives of this third phase project are to do maintenance at the existing rehabilitation plots and to continue monitoring hydrological data at the two check dams. The outcomes from the project will contribute to the rehabilitation of the degraded area through tree plantings in the 5 ha plots and water replenishment by the restoration of ground water levels in the AHNFR.

MATERIALS AND METHODS

The Maintenance of the Existing Rehabilitation Plots of 5 ha in Degraded Areas in the AHNFR

A total of 1000 saplings were planted in this planting plot in 2016 through the Water for Life Project Phase 2: 2016-2017. There were 5 planting blocks that have been established where each block is 1 hectare and has been planted with 200 seedlings. The species planted were tenggek burung (915 trees), meranti paya (80 trees), and ramin melawis (5 plants). The last census conducted in December 2017 found that the survival percentage was as high as 74%. Therefore, in Water for Life

Phase 3: 2020-2021, the re-census of tree survival was to determine the current percentage of tree survival as well as the growth rate of trees planted (Figure 3). Once the re-census is completed, the replanting of trees will be conducted to replace the dead trees.

Check Dam Maintenance and Monthly Hydrological Data Monitoring

Two small check dams were established at Parit Pulai and Parit Gantung during the Phase II Water for Life Project (2016–2017). These check dams were constructed across the small drains near the border of the AHNFR, which functions to delay and reduce the water outflow from the forest reserve, increase the groundwater table and maintain forest surface wetness to prevent forest fires, and calculate the flow rates before and after the application of the check dams. The maintenance activities of these check dams have been carried out in the third phase. The rain gauge was installed in the Kompleks Penghulu vicinity on January 7, 2020. The water-level sensor was installed near the check dam to record the water-level changes automatically throughout the year. Readings from this equipment were collected monthly in the study area. Manual measurements of groundwater level around the stream leading towards the check dam were also conducted to identify the current water level status as a result of the water barrier's construction.

RESULTS AND DISCUSSION

Covid-19 pandemics have slowed down and disrupted the activities that had been planned. The re-census results found that the tree survival rate is at 0% in Block 1, Block 2, and Block 3. Field observations found that the tree mortality in Block 1, Block 2, and Block 3 were caused by forest fires that occurred in 2019. The forest fire that occurred around June 2019 was caused by the agricultural land adjacent to the forest reserve (Figure 2). The fire from the agricultural land was out of control and had spread into the forest reserve and destroyed the planting plots (Block 1, Block 2, and Block 3). According to the *Penghulu Mukim,* the forest fire was successfully controlled by the Fire and Rescue Department, Johor State Forestry Department and also the Mukim Ayer Hitam Volunteer Fire Brigade team.

The percentage of tree survival in Block 4 and Block 5 is also low where 18% and 3% at Block 5 and Block 4 respectively. Field observations have found that the factors that caused the low survival rates could be due to wild boar attacks as well as competition with naturally growing trees. The effects of the wild boar attack can be seen where the white PVC spikes planted next to the trees have been shifted and scattered on the forest floor. Planted trees were unable to live well, whether because their growth is stunted, slowed, or dies when under the shade or canopy of the forest formed by the trees that grow naturally (natural regeneration). In contrast, planted trees were observed to grow rapidly in some areas that are not covered by a canopy.

Block 1, Block 2, and Block 3 were only overgrown with *resam* and ferns after the fire. These plants are an indication of peat swamp forest areas that have been degraded by fire or encroachment. The presence of weeds is also an indication that the area is at risk of fire (fire-prone area).

Figure 2 Photos during the forest fire within the planting block in Forest Compartment 18 in June 2019

Figure 3 Measuring the tree base diameter using Digital Calliper

The next plan is to replant the trees in suitable planting blocks, which will be determined later based on the accessibility and condition of the area. It was found that some areas in Block 2 and Block 3 that burned in 2019 were easily submerged during the rainy season (due to peat subsidence). Therefore, it is important to determine the best time to plant trees in this area so that the trees have enough time to become stable before being flooded during the rainy season. In addition, techniques such as mounds or using boxes can be used in areas that are submerged in water, however, if it is too deep, this area should be avoided to be replanted. The tree saplings for the next tree planting have been prepared. It consists of the following species, Bintangor Gambut (*Calophyllum* *ferrugineum*) (200 saplings), Sentul (*Sandoricum koetjape*) (100 saplings) and Kasai (*Pometia pinnata*) (200 saplings).

Figure 4 Measuring the height of a tree using a height pole

During this Phase III project, the check dam at Parit Pulai and Parit Gantung has been repaired and the outflow has been redesigned to a v-notch shape (Figure 5). The rainfall station was set up at Kompleks Penghulu (KP), Mukim Ayer Hitam using an automatic rain gauge with a tipping bucket of 1.0 mm/tip and connected to the event logger. Besides this, a conventional rain gauge was also set up for backup. The rainfall recorded in 2021 was 2,386 mm, which is lesser than in 2020 with 2,456 mm. The highest rain was received in September, while March was the second peak of the bimodal pattern of rainfall.

Figure 5 Check dam maintenance and redesign to v-notch shape at Parit Pulai check dam

Rainfall influences the water level in the drain. Discharge was not available from the check dam at Parit Pulai in February and March 2021 as it coincided with the little rainfall in February 2021 (Figure 6). The fluctuation of water level at this check dam ranged from 34.2 to 52.5 cm with an average of

43.5 cm. Meanwhile, the water level at Parit Gantung before the maintenance started ranged from 7.6 to 17.4 cm with an average of 11.1 cm (Figure 6).

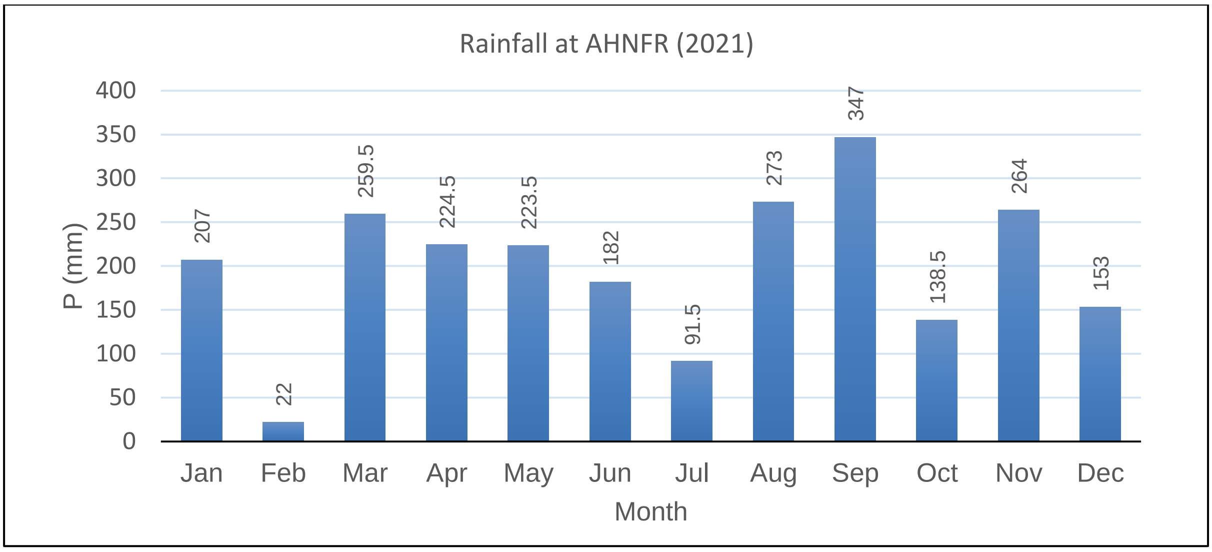

Figure 6 Monthly rainfall distributions at Ayer Hitam North Forest Reserve in 2021 shows the driest month was in February and the wettest month was in September

The groundwater level (gwl) was measured monthly under forest and oil palm canopies (Figure 7). Measurement started at point 1, which is located at the check dam and the distance between each point is 50 m. The groundwater levels under the forest canopy at Parit Pulai fluctuated less than those under the oil palm canopy (Figures 8 & 9).

Figure 7 Preparation for manual ground water level monitoring

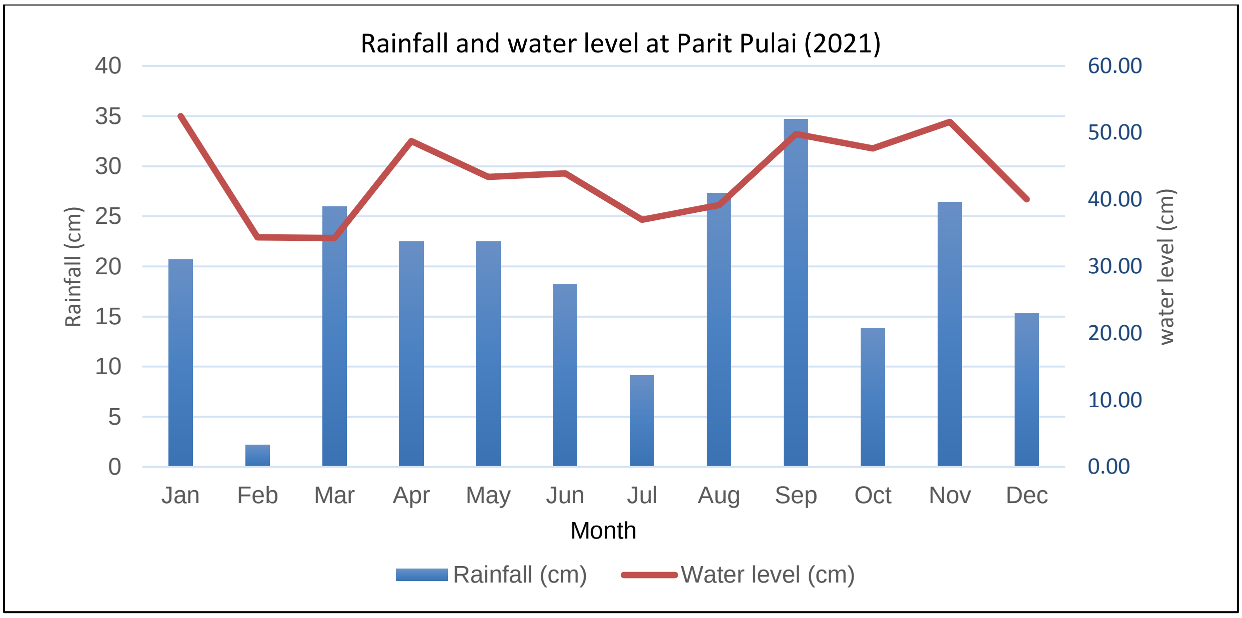

Figure 8 The fluctuation of water levels in the drain following the rainfall at Parit Pulai

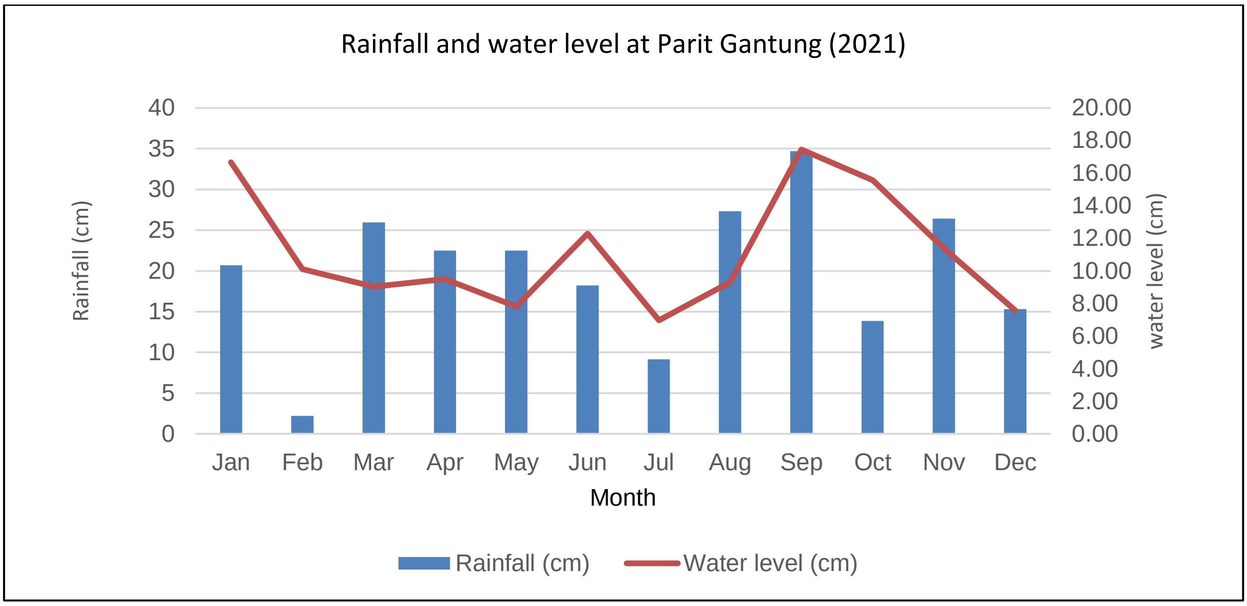

Figure 9 The fluctuation of water levels in the drain following the rainfall at Parit Gantung

In September 2021, gwl was found closer to the forest surface due to the high rainfall and was low in February due to less rainfall. The gwl under the forest canopy ranged from 51.3 to 93.4 cm, which is higher than gwl under the oil palm canopy which ranged from 67.6 to 86.9 cm (Figures 10 & 11).

Check dam at Parit Gantung is located 60 m from the border of the forest reserve. The dam is established in the plantation area. The groundwater levels were measured under the forest canopy along the forest plantation's border, not inside the forest. The gwl pattern was not similar to what had been observed in Parit Pulai. The fluctuation of gwl ranged from 55.5 to 107.4 cm under the forest canopy while under theoil palm canopy ranged from 64.0 to 111.0 cm (Figures 12 & 13).

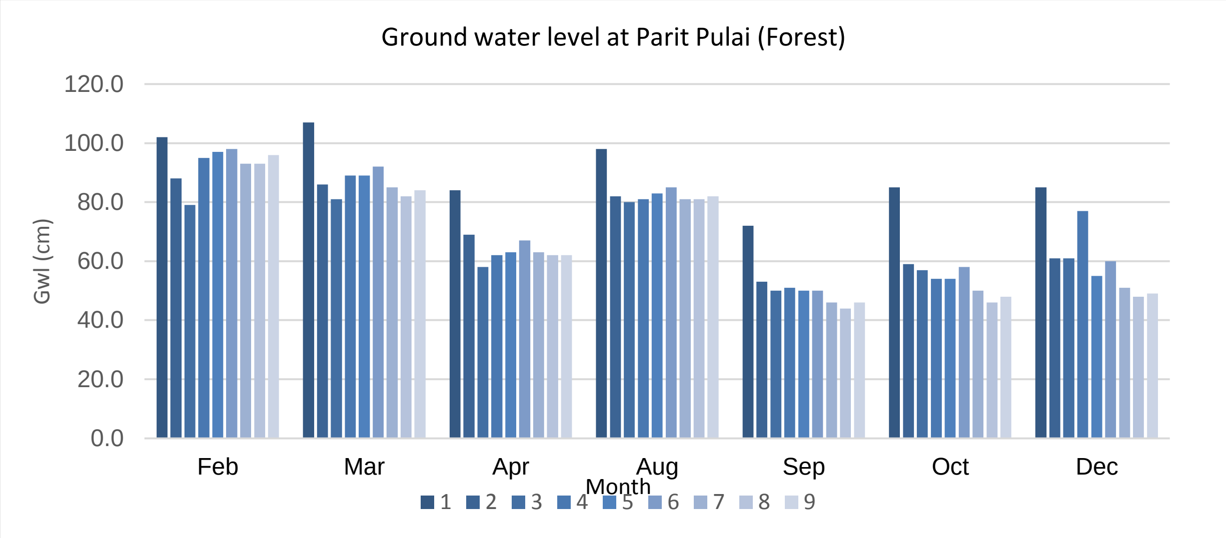

Figure 10 The ground water level under the forest canopy away from the surface as the distance approach to the drain

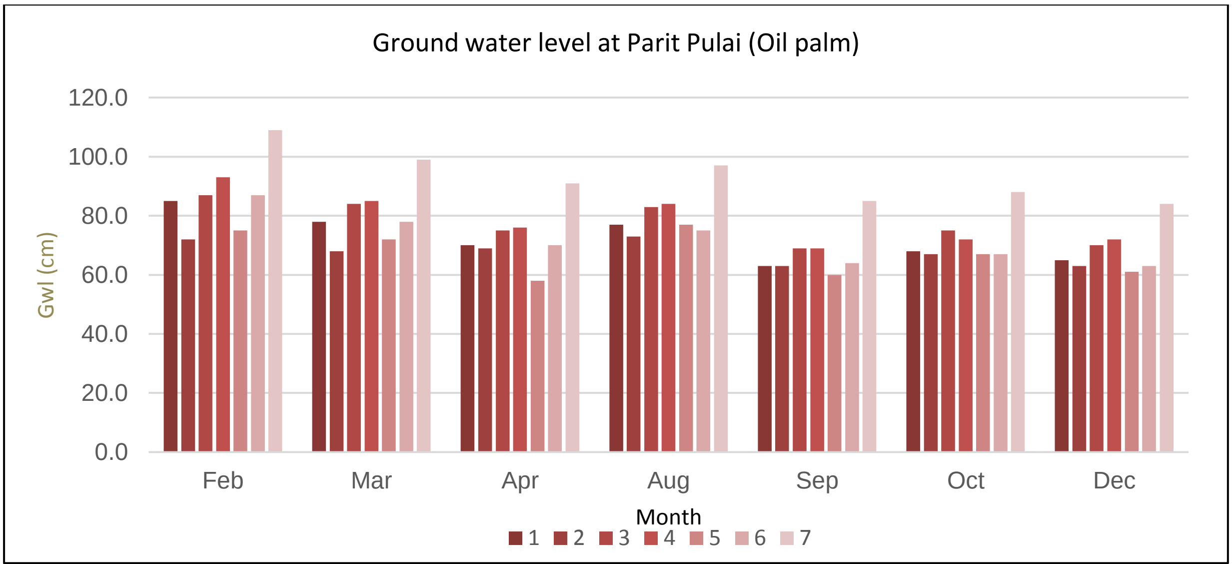

Figure 11 The ground water level under the oil palm canopy getting lower as it is far from the drain

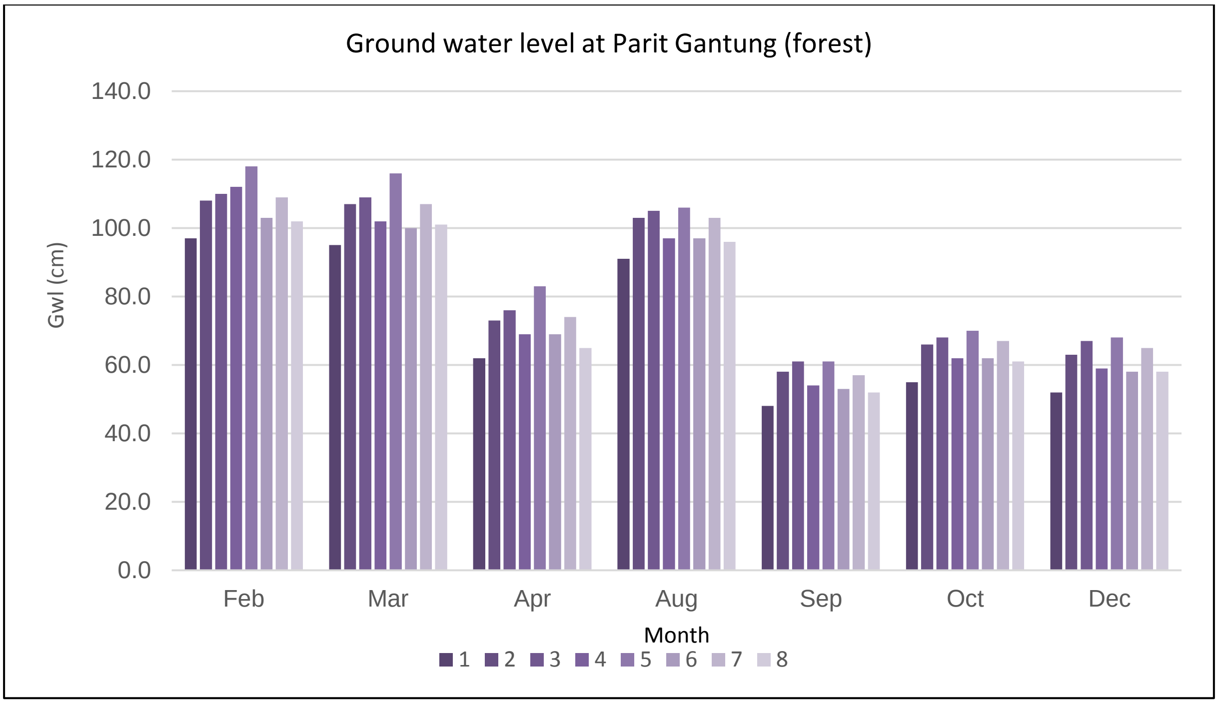

Figure 12 The monthly fluctuation of water levels under forest canopy alongside the border of the oil palm plantation

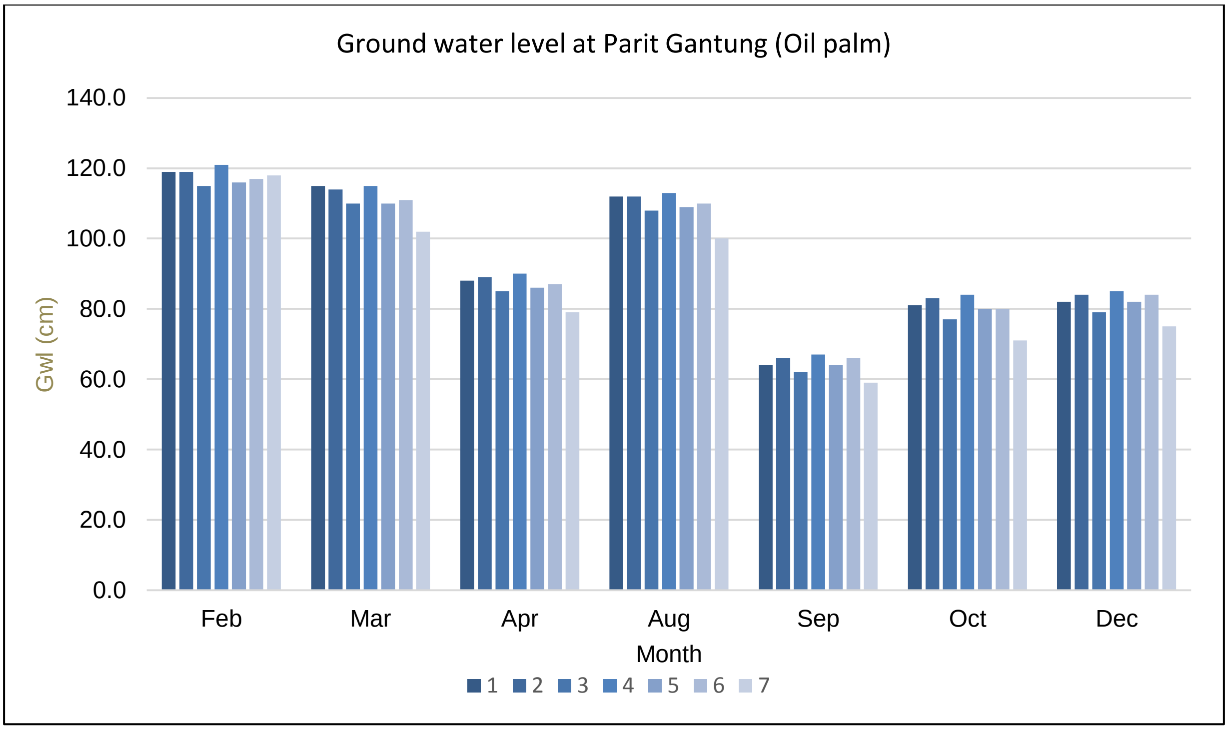

Figure 13 The monthly fluctuation of ground water levels under oil palm canopy from the drain into the plantation area

CONCLUSION

Observation of the groundwater level in 2021 has shown that the water level was increased by 21.97 cm after redesigning the check dam from a rectangular to a V-notch shape. The outflow was reduced from 0.252 m^3/s to as low as 0.0819 m^3/s. The amount of 5.98 billion litres of water volume was conserved in the forest reserve in 2021. In terms of catchment, about 0.00651 billion L/ha/year has been replenished in 2021, which is higher than in 2020. As for the check dam at Parit Gantung, the outflow was reduced from 0.0988800m^3/s to 0.0002547 m^3/s. It is estimated that 3.11 billion litres will be conserved in the forest reserve in 2022.

The rehabilitation of the degraded forest area and water table through the construction of the small check dam has been successfully implemented at AHNFR. The V-north shape of the check dam was found suitable to increase the water level and redesigning the outflow indirectly helps to maintain land surface wetness for preventing forest fires. The water replenishment result from this project is part of the Coca-Cola Company's global sustainability commitment to water strategy to replenish 100% of the equivalent volume of water consumed in the company's products and production.

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DETERMINATION OF THE TRANSPIRATION AND WATER USE EFFICIENCY (WUE) OF SELECTED MANGROVE SPECIES

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The study on transpiration and water use efficiency of mangrove species was still lacking in Malaysia. Information on the hydrological characteristic of the mangrove plant related to its physiological traits is often neglected. Therefore, the study has been undertaken to fill in the gap of information as a value-added to the conservation effort of mangroves. This information is also important to clarify gas exchanges at the different forest ecosystem levels. Such studies have been conducted to clarify gas exchanges in dipterocarp forests but less has been done for mangrove forest species. Therefore, this study aims to provide fundamental data on the transpiration and WUE of mangrove forest species. The observation was conducted in the morning and afternoon using Li6400XT on *Rhizophora apiculata* (bakau minyak), *Rhizophora mucronata* (bakau kurap), *Avicennia officinalis* (api-api ludat), and *Avicennia alba* (api-api putih). This paper, therefore, will report the preliminary result of the observation of selected mangrove species at Sungai Hj. Dorani mangrove forest, Selangor and Matang mangrove forest, Perak, Malaysia. The transpiration rate for Sg Haji Dorani was higher in *Avicennia* species compared to *Rhizophora* species in the morning and afternoon. Transpiration rates varied from 1.85 to 2.76 mmol m^{-2} s^{-1} in the morning and from 0.28 to 1.50 mmol m^{-2} s^{-1} in the afternoon for both *Avicennia* species. *Rhizophora* shows the highest transpiration rates in the afternoon (0.30 - 0.46 mmol m^{-2} s^{-1}) compared in the morning (0.33 - 0.34 mmol m^{-2} s^{-1}). *Rhizophora mucronata* and *Avicennia alba* were recorded as having higher water use efficiency in the morning compared with other species. In the Matang mangrove forest, transpiration rates range between 1.51 – 2.05 mmol m^{-2} s^{-1} (morning) and 1.46 – 2.55 mmol m^{-2} s^{-1} (afternoon) for *Avicennia* species while, for *Rhizophora* species was ranged between 0.65 – 0.82 mmol m^{-2} s^{-1} (morning) and 0.43 – 0.57 mmol m^{-2} s^{-1} (afternoon). The *Avicennia alba* and *Rhizophora apiculata* perform higher water use efficiency in the morning and afternoon in the Matang mangrove forest. The data obtained from this study are useful information for mangrove forests. It is anticipated that there will be more baseline data pertaining to transpiration, water use efficiency, and photosynthesis of mangrove forests available in the future for scientific reference.

Keywords: Photosynthesis, stomata conductance, gas exchange, mangrove species, water cycle

INTRODUCTION

Mangrove forests dominate the world's tropical and subtropical coastlines, which provide a habitat for rich biodiversity (FAO 2003). They provide a wide range of ecological services that protect the coast from erosion, buffer adjacent marine ecosystems (often coral reefs) from terrestrial inputs and are nursery grounds for important commercial fish species and habitats for migratory birds. Mangroves are a group of highly salt-tolerant woody plants. The high-water use efficiency of mangroves under saline conditions suggests that regulation of water transport is a crucial component of their salinity tolerance (Ruth & Catherine, 2015). Since water acquisition is more energetically costly in saline than in non-saline soils, mangroves have evolved a range of adaptations that facilitate efficient water use during photosynthetic carbon gain during the day and reduce losses of water to saline soils at night. Mangroves have a number of properties, from the scale of the arrangement of leaves in the canopy to microscopic structures within leaves, which contribute to high photosynthetic water use efficiencies.

A plant needs water for its physiological processes including photosynthesis. Water used in photosynthesis will be released into the atmosphere by transpiration processes. The ratio of photosynthesis and transpiration in the plant will explain the water use efficiency (WUE) of the plant. Mangrove plants will filtrate saline water and transpire fresh water into the air. These processes are useful in cloud formation and the source of rainwater. Therefore, mangrove plays an important role in maintaining the water cycle. The study on transpiration and water use efficiency of mangrove species was still lacking. Information on the hydrological characteristic of the mangrove plant related to its physiological traits is often neglected. Therefore, a study must be undertaken to fill in the gap of information as a value added to the conservation effort of mangroves. This information is also important to clarify gas exchange at the different forest ecosystem levels. Such studies have been conducted to clarify gas exchange in dipterocarp forests but less has been done for mangrove forest species. Therefore, this study aims to provide fundamental data on transpiration and WUE for scientific reference.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Sg. Haji Dorani in Kuala Selangor, Selangor and Matang mangrove forest, Perak, Malaysia. Sg. Haji Dorani is located about 90 km to the north of Kuala Lumpur, near Sabak Bernam on the west coast of Peninsular Malaysia. The Sg Haji Dorani plot was established as a mangrove innovative experimental plot with an area of 200 m x 75 m. It was a 12-year-old mangrove stand dominated by *Rhizophora spp*. and *Avicennia spp*. The highest temperature was recorded in October at 27.7^{o}C while the lowest was in July at 26.2^{o}C with an average annual temperature of 26.9^{o}C (Wan Rasidah et al. 2019). The Matang Mangrove forest is located in Perak along the western coast of Peninsular Malaysia and occupies an area of approximately 40,000 ha which were dominated by *Rhizophora* species (Ariffin & Mustafa 2013). Both study areas are subjected to the climate of Peninsular Malaysia which is mainly influenced by two monsoons during the year: the Southwest monsoon from May to September and the Northeast monsoon from November to March.

The period of change between the two monsoons is a transitional period that occurs in April and October. Heavy rainfall often occurs during these two transitional periods (Desa et al. 2001; Suhaila & Jemain 2007). The tropical climate is experienced year-round with an average annual precipitation of 2000 – 2800 mm per year. The relative humidity ranges from 80 to 90% and the temperature averages from 22 to 33^{o}C throughout the year.

Selection of Mangrove Species

Two species were selected in this study: *Rhizophora* and *Avicennia.* The *Rhizophora* is a family from the tropical and sub-tropical groups. It has 16 genera with 120 species that consist of woody plants or shrubs. *Rhizophora* is a dominant genus of the most widespread mangrove family, the Rhizophoraceae. The genus *Avicennia* comprises 8 species of mangrove trees that occur in intertidal zones of estuaries and seabeds found in tropical and temperate regions spanning throughout the world (Hrudayanath et al. 2016). It has ecological, economic, and ethno-medicinal benefits. These species dominated both Sg. Haji Dorani and Matang mangrove forests.

Leaf Gas-Exchange Measurement

Measurements were conducted in the field using a LI-6400 portable photosynthesis system (LI-COR, Lincoln, NE, USA) connected to a standard 6 cm^2 cuvette. Fully expanded, sunlight leaves were clamped in the sensor cuvette, maintaining their natural position. The leaves were flushed with ambient air (flow rate 500 mol m^{-2} s^{-1}), of which the temperature and relative humidity were simultaneously recorded. Gas-exchange measurements, including CO_2 fixation rate (*A*), stomatal conductance to water vapour (*gs*), and transpiration rate (E), were logged after readings reached stable (1–3 min). The infrared gas analyser was matched to reach equilibrium before every measurement. Measurements were conducted with ambient temperature, while CO_2 reference concentration was maintained at 400 µmol mol^{-1}. The photosynthetic photon flux density was set at 1600 µmol m^{-2}s^{-1} to ensure that light-saturated photosynthetic rates were reached. All measurements were performed in the morning (between 9:00 and 12:00 h) and afternoon (between 02:00 and 04:00 h).

RESULTS AND DISCUSSION

Transpiration Rates of *Rhizophora* and *Avicennia* Species in Matang and Sg. Haji Dorani Mangrove Forest

Transpiration rates observed for *Rhizophora* and *Avicennia* species (Figures 1 & 2) were shown to be varied according to location and mangrove age. Matang mangrove forest was established since 1902 and the mangrove stand aged between 15 to 30 years while the mangrove stands in Sg. Haji Dorani was about 12 years old. The composition of the mangrove stand in Matang was also dense compared to the one in Sg. Haji Dorani. The *Rhizophora* species in Matang (Figure 1) transpired water at the rates between 0.65 mmol m^{-2} s^{-1} (±SD 0.43) and 0.82 mmol m^{-2} s^{-1} (±SD 0.36) in the morning while at the Sg. Haji Dorani was between 0.33 mmol m^{-2} s^{-1} (±SD 0.31) and 0.34 mmol m^{-2} s^{-1} (±SD 0.12). In the afternoon observation, a reduction of transpiration rates occurred in both species at all locations except for *R. mucronata* at the Sg. Haji Dorani. The rates were reduced to 0.43 mmol m^{-2} s^{-1} (±SD 0.27) and 0.57 mmolm^{-2} s^{-1} (±SD 0.0.29) in the Matang forest, however, in Sg. Haji Dorani the reduction only occurred to *R. apiculata* at 0.30 mmol m^{-2} s^{-1} (±SD 0.40). *Rhizophora mucronata* showed the opposite values at 0.46 mmol m^{-2} s^{-1} (±SD 0.16) in the afternoon. There is no certain explanation for this situation however, several conditions lead to variation in transpiration rates, for example, the leave anatomical (stoma size, density, and position), environmental variability, and photosynthetic activities. The most influential factor for leaf transpiration activities is stomatal conductance (*gs*). Since the stomatal conductance is the most influential factor for determining transpiration rates, the leaf stomatal conductance is also known as the most variable parameter on the pathway and in a physical approach of transpiration modelling as reported by the pioneer physiologists like Farquhar et al. (1980) and Goudriaan et al. (1985). The regression analysis between transpiration values and stomatal conductance explained that 70 to 99% of those values are associated and the association was stronger in the afternoon. Sometimes, the atmospheric demand for water vapour is also affecting the transpiration rates but this was not evident in this study. The vapour pressure deficit (VPD) did not vary much throughout the measurement.

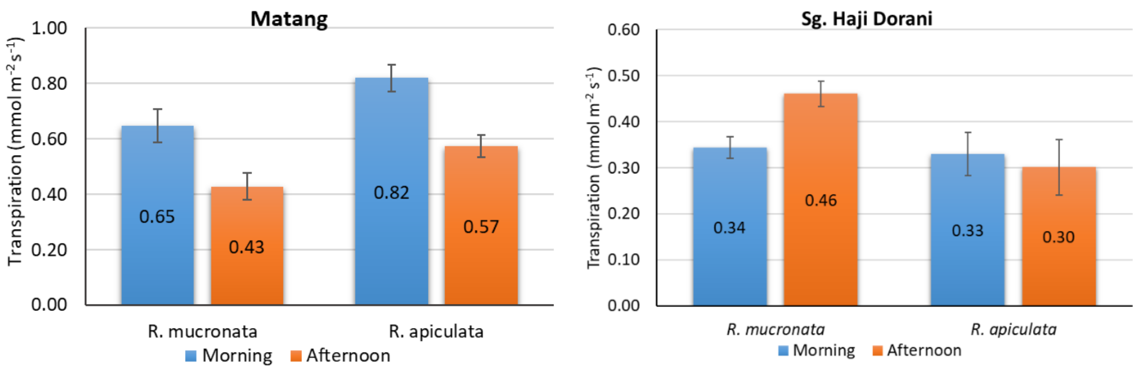


Figure 1 The transpiration rates observed for *Rhizophora mucronata* and *Rhizophora apiculata* at different location

In the *Avicennia* species (Figure 2), transpiration rates at the Matang mangrove forest were stable during morning and afternoon observation. The values were not varied much between the measurement times. The *A. officinalis* transpired water at the rates of 2.05 mmol m^{-2} s^{-1} (±SD 0.42) in the morning and 2.55 mmol m^{-2} s^{-1} (±SD 1.44) in the afternoon. The stable fluctuation was also observed for *Avicennia alba* in the Matang forest which varied between 1.51 mmol m^{-2} s^{-1} (±SD 0.82) for morning observation and 1.46 mmol m^{-2} s^{-1} (±SD 0.65) in the afternoon. A large reduction in transpiration rates for *A. officinalis* was observed in Sg. Haji Dorani was reduced from 2.76 mmol m^{-2} s^{-1} (±SD 1.14) in the morning to 0.28 mmol m^{-2} s^{-1} (±SD 0.13) in the afternoon. The *A. alba* showed stable transpiration rates throughout the observation at 1.85 mmol m^{-2} s^{-1} (±SD 1.03) in the morning and 1.50 mmol m^{-2} s^{-1} (±SD 0.99) in the afternoon.

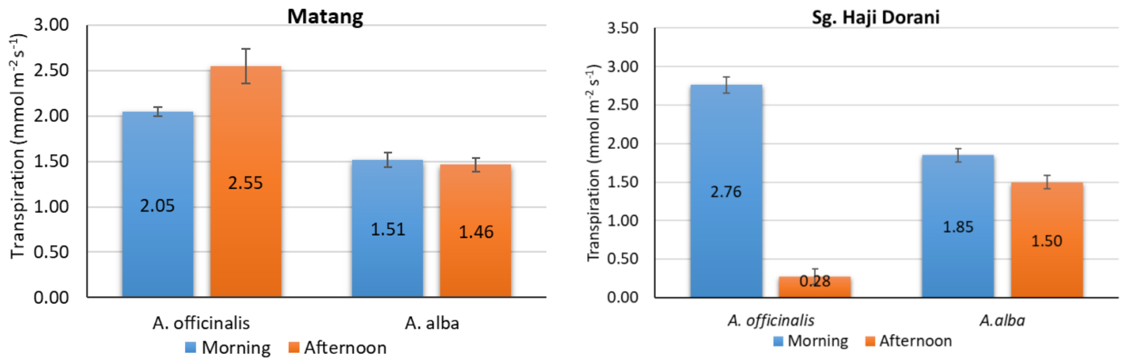
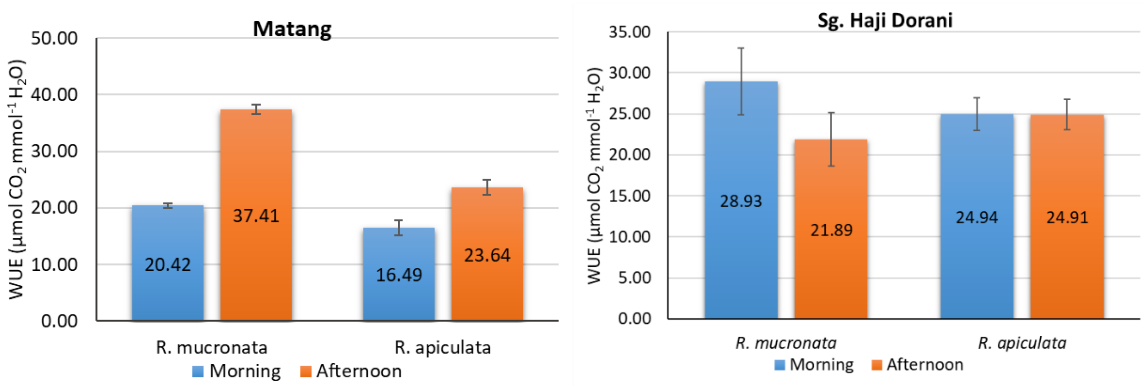


Figure 2 The transpiration rates observed for *Avicennia officinalis* and *Avicennia alba* at different location

Water Use Efficiency of *Rhizophora* and *Avicennia* Species in Matang and Sg. Haji Dorani Mangrove Forest

The water use efficiency (WUE) is the ratio of photosynthetic carbon assimilation (*A*) and transpiration (*E*). Variability in photosynthesis and transpiration activities determines the WUE values. The variability of WUE for *Avicennia* species in Matang forest was stable and not much differences between morning and afternoon observations. The WUE rates were between 5.44 (morning) and 5.55 (afternoon) µmol CO_2 $mmol^{-1}$ H_2O in *A. officinalis* while 10.81 (morning) and 9.83 (afternoon) µmol CO_2 $mmol^{-1}$ H_2O in *A. alba.* The *R. mucronata* recorded WUE values between 20.42 (morning) and 37.41 (afternoon) µmol CO_2 $mmol^{-1}$ H_2O; while the *R. apiculate* ranged between 16.49 (morning) and 23.64 (afternoon) µmol CO_2 $mmol^{-1}$ H_2O. In Sg. Haji Dorani, WUE recorded above 20 µmol CO_2 $mmol^{-1}$ H_2O for both *R. mucronata* and *apiculata* during morning and afternoon observations. The WUE of the *Avicennia* species slightly varied in the range between 9.34 and 16.01 µmol CO_2 $mmol^{-1}$ H_2O in the morning while getting slightly bigger at 19.37 (*A. officinalis*) and 25.60 (*A. alba*) µmol CO_2 $mmol^{-1}$ H_2O in the afternoon. The large variability of WUE for morning and afternoon observation in *A. officinalis* was due to the large differences between the photosynthesis and transpiration values. The intercellular activities during photosynthesis affect the WUE value. A lower intercellular CO_2 concentration during photosynthesis will correspond to a higher WUE (Cernusak 2018). This means that the WUE depends on the extent of drawdown in the CO_2 concentration from the atmosphere to the leaf interior.



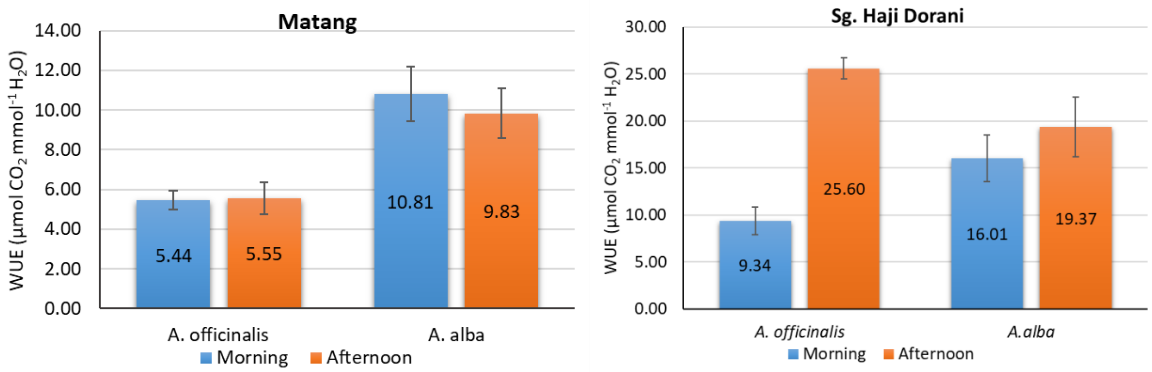


Figure 3 The water use efficiency of *Rhizophora* and *Avicennia* species in Matang and Sg. Haji Dorani mangrove forest

CONCLUSION

The rate of transpiration by mangrove species can provide basic information on the specific ability of mangrove stands in regulating the local climate, contributing to the water cycle (forest for water) and oxygen supply to life. Transpiration is a component in the hydrological cycle that contributes to the mass of water vapour in the air. Water use efficiency is an effective feature for assessing the response of plant ecosystems to climate change. This information was baseline data which was based on the short-term study to fill in the gap of information for mangrove physiological data for future scientific references and needs further exploration to understand this unique species.

ACKNOWLEDGEMENT

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MODULAR CONCEPT OF FOREST MOBILE BRIDGE IN ASSISTING FOREST ACCESSIBILITY

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A bridge is one of the important components of forest roads. Among others including forest road design and route alignment, the bridge is constructed permanently for stream crossing. Permanent bridges such as culverts are normally designed for super heavy loads which need heavy machinery for installation and removal. The installations of these bridges are costly and time-consuming and yet numbers of streams would be crossed. Furthermore, these permanent bridges are subjected to failure during storms, erosion, and sedimentation which lead to higher maintenance costs. These bridges are exposed to structural damage during the storms impacted by the high velocity of stream water flow. During the harvesting period, these bridges are maintained by the logging contractor and removed or left to deteriorate at the end of the use period. This situation leads to a problem for the Forestry Department to carry out the post harvesting activities as it is regulated to maintain forest health. This situation shows the need for design innovation for portable bridges that could ease transportation, installation, and removal for reuse at multiple sites. However, joints are often the weakest points in this kind of portable modular bridge. Therefore, this study was carried out to determine the applicability of the joint system in the modular concept of the portable bridge.

Keywords: Mobile bridge, modular concept, joint system, stainless steel

INTRODUCTION

Forest harvesting in Malaysia is currently being carried out deep inside the forest where accessibility becomes one of the problems when crossing the streams. Stream or river crossing requires a bridge, and under the current specification, this bridge is built with a log stringer (Figure 1) for only temporary usage and removed or left to deteriorate at the end of the use period (Taylor et al. 1995). Almost any species of wood would allow usage for less than three years. Proper culvert design with hardwood species for the sill log will extend the service life (Chow 2018). The forest manager faced this problem to run forest and soil treatment in the logged-over area for post-harvesting activities. Most of the time, upon completion of logging activities, these temporary bridges are not maintained and will deteriorate and collapse due to the high velocity of water flow, erosion, and sedimentation (Leete 2008).

Therefore, there is a need to have a suitable, cost-effective, and easy-to-handle but durable bridge that can be used to access the logged-over forest to carry out post-harvesting activities. Taylor et al. (1995) suggest a portable bridge to ease transportation, installation, and removal for reuse at multiple sites that would reduce the construction cost compared to a permanent structure, and at the same time, reduce potential water quality problems (Brinker & Taylor 1997). Nowadays, there are several portable bridges developed to reduce the environmental impacts, but still, the installation and dismantling need heavy machinery. One of the necessary criteria in designing these portable bridges is the consideration of easy assembly, installation, removal, and transportation.

Figure 1 Forest Bridge made of log stringer

In the forestry industry, light construction equipment and minimum field cost and work for installation and removal are expected (Taylor et al. 1995). The ability of portable bridges to serve multiple installations makes them much more economically feasible than a permanent structure. In addition, they have the potential to avoid water quality problems (Taylor et al. 1995). A prototype of a portable forest mobile bridge has been developed by FRIM (Figure 3) with a modular concept (Figure 2). One of the requirements of this concept is the reduced weight where the material replacement is found to be more effective and economical than a structural modification in reducing weight. The bridge used a C-channel of 2”x 4” as the main structural shape that is produced by an extrusion process where the hot metal is pressed through a die to form the structural profile with good form ability, weld ability, machinery ability, and corrosion resistance. The truss concept is used in overall segment design. To avoid buckling problems, the framework comprises a number of triangulated members. This will also allow long members to handle compression and short members to handle tension at the same time. The prototype consists of 3 segments with different lengths. The centre segment length is 3.5 meters. The right and left segments’ lengths are 1.5 m each and the final segments are sided ramps with a length of 1m each. The overall length of this prototype is 6.5m, however, the maximum allowed stream span is only 5.5m in which a 1 m bridge at both sides would be firmly footed on stream banks. These segments are joined using the connector by rod and connection plates.

Figure 2 Modular concept of Forest Bridge

In timber structural components, joints are often the weakest points and therefore knowledge of the mechanical behaviour of the joints in designing timber structures is critical. A few factors that might affect the performance of the joints are the geometry of the members and joints, the orientation of the load concerning timber grain, and clearance and friction between the joint members (Xu et al. 2014). This modular bridge is evaluated as a single system as the durability of each component relies on the durability of other components (Dexter et al. 2001). Furthermore, connections are part of bridges that are subject to failure due to heavy loading (Crocetti & Edlund 2003) and therefore they were enhanced for the safety factor. The design is based on mechanical connections with bolts type of fastener. It is relatively inexpensive and does not require specialized skills or equipment for installation. The advantage of this mechanical connection is can easily be installed and dismantled. Easy dissembling also allows the bridge structure to be properly maintained in extending the service life.

MATERIALS AND METHODS

The prototype was built with 2 main girders for supporting trespassing. There are 8 unit connectors that were welded to the main bridge structure consisting of 2 main girders. In each girder, 4 of the connectors were welded to the C channel beam as shown in Figure 3. Based on forest road and terrain conditions, a four-wheel drive vehicle is the best selection for transporting modular and mobile forest bridges for installation and dismantling for each stream crossing. The load design is based on a four-wheel drive Toyota Hilux with a double cabin in which the Gross Vehicle Weight is approximately 3000 kg. The live load factor in load design is referred to as AASHTO HS20 which is 1.75 (Liu 2007). The imposed load for the simulation is 51.503 kN (3000kg x 1.75 x 9.81 m/s2). From ANSYS Static Stress analysis, results of stress, strain, deflection, and safety factor could be extracted (Mamat et al. 2019). Assignment of loading is based on the 3-points bending test (Foster et al. 2017; Ghazijahani et al. 2017). Static load was assigned at the desired nodes on top of the specimen as a nodal force with a downward direction (Zheng & Fox 2017).

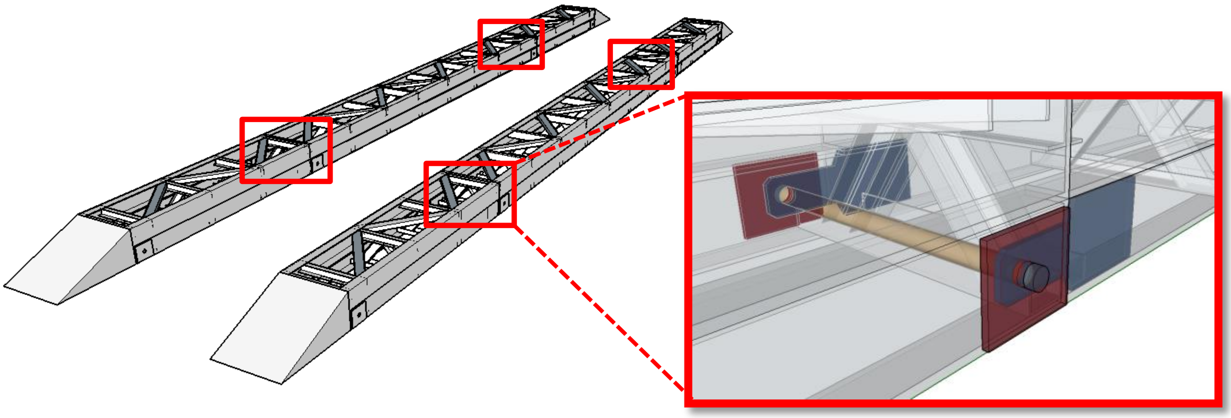

Figure 3 Connector in joining the modular segment of bridge structure

Four specimens were simulated based on the three different 3D models. Specimen 3D models were built regarding the connector design and location based on the prototype of a short-span bridge. The fourth specimen was simulated with effective loading. The prototype was built with 6 segments that connected with 8 units of connectors. Therefore the distributed loading on a single unit of connector is 6437.875 N. The first specimen was built to analyze the strength of a simple beam connected with the connector (Figure 4). The second specimen was built based on the bottom side of the girder design which consists of beams connected with dual connectors. The applied loading for the second connector is 12875.75 N (Figure 5). The third specimen was originally designed for the girder as the prototype which was also connected using the same connector design and applied 12875.75 N loading (Figure 6). The fourth specimen is an extension analysis using the same model as the third specimen but different loading value. In this case, the value of loading is calculated based on the actual location of the connector which is located at 1.5m from the support point. The effective loading for the fourth specimen is the ratio of the length of the connector location to the girder mid-span, 6.5 m which is 5942.31 N (Figure 7). All specimens were built for 2 m in total where 1 m in length for each side. In this particular study, stainless steel was used as the material for all specimens in the simulation. All components was in set as separated with a 0.2 coefficient of friction at the connection.

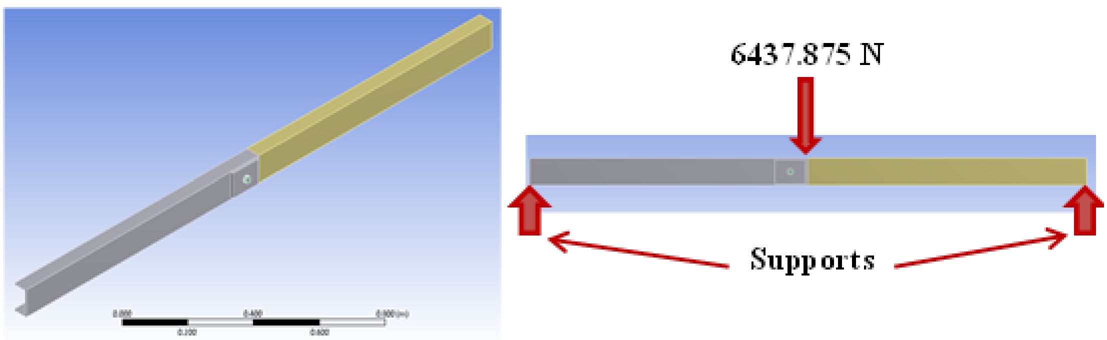

Figure 4 Specimen 1

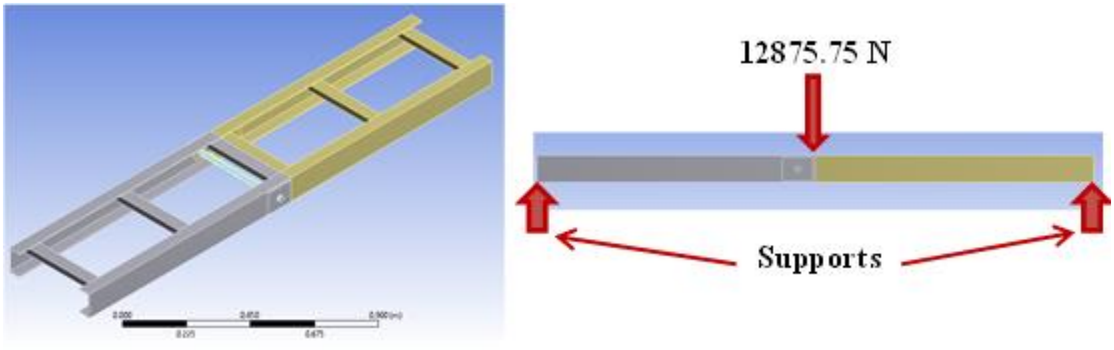

Figure 5 Specimen 2

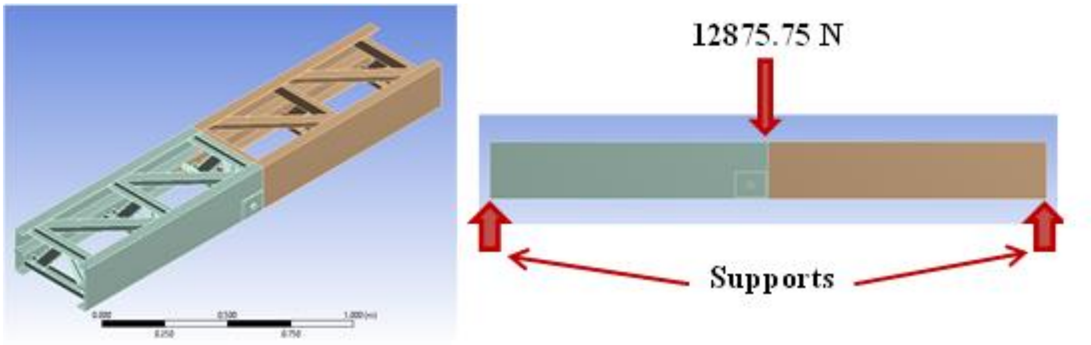

Figure 6 Specimen 3

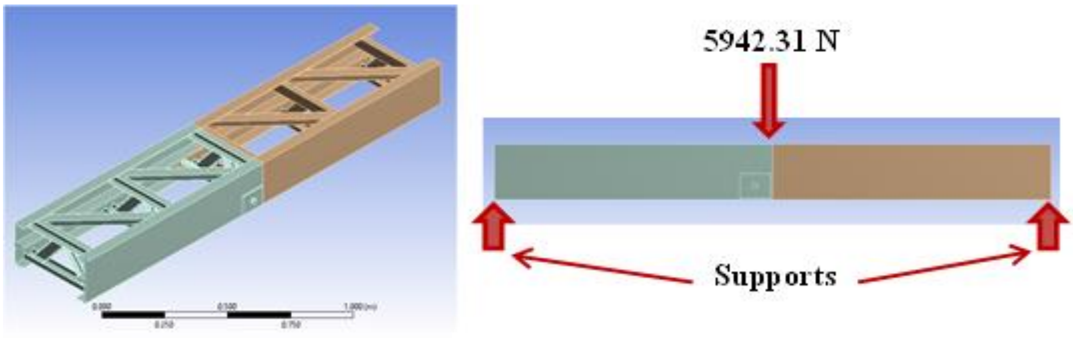

Figure 7 Specimen 4

RESULTS AND DISCUSSION

The result of deformation, stress, strain and safety factors was extracted from the simulation for further analysis. Path line construction geometry was constructed at the top side of the specimen for stress-strain analysis. Table 1 shows the summary of deformation, stress, strain, and safety factor results for four models analyzed based on static stress analysis with 3 points bending setup.

Table 1 Summary of simulation results

Specimen	Deformation (m)	Strain (m/m)	Stress (Pa)	Safety Factor
1	0.00745	0.00176	312000000	0.803
2	0.00191	0.00132	264000000	0.94611
3	0.000319	0.000691	138000000	1.82
4	0.000153	0.000328	65400000	3.82

Table 1 also shows that deformation, strain, and stress were significantly reduced from the first to fourth analysis. The deformation significantly decreased from 7.45E-3 m to 1.53E-4 m. The result of stress and strain was also observed significantly reduced from 3.12E8 Pa to 6.54E7 Pa and 1.76E-3 m/m to 3.28E-4 m/m consecutively. However, these results contradict the safety factor which shows a dramatic increase from 8.03e-1 to 3.82. This safety factor value indicates the condition to allow the structure to safely deform. The minimum value of safety factor for standard designing is 2.0 shows that the fourth analysis contributes 3.82 passing the minimum design standard where the structure could be safely used. Reduction of deformation, stress and strain and increase in safety factor shows an enhancement of design, although the loading applied accordingly to the number of connectors in that specific 3D model.

The strength of the structure could be evaluated by stress-strain analysis. Figure 8 below shows the stress-strain graph referring to the bending result of four different specimens extracted on the path that has been constructed on the model. At the point of measured stress, the strain was also evaluated. The graph shows the distribution of stress and strain of the model analyzed for specimens 1 to 4. Shorter point distribution in the stress-strain graph shows higher stiffness of the specimen. Specimen 4 shows the highest stiffness of the structure followed by specimen 3, specimen 2. The lowest structure stiffness is specimen 1. Besides, the distribution of stress and strain points for all specimens in that stress-strain graphs trend in the same direction for all specimens. This is because all specimens apply the same material and use the same connector design. Length of trendlines for all varies due to different design and loading values.

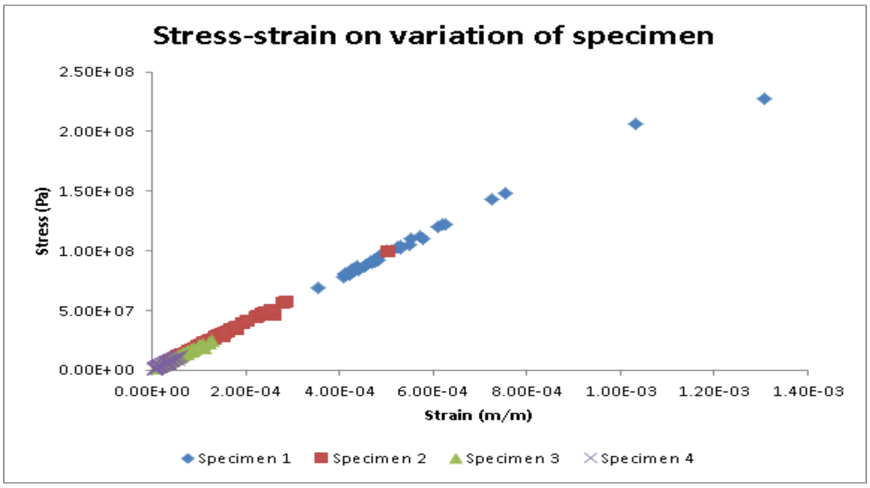

Figure 8 Stress-strain point distribution of analyzed specimen

Figure 9 shows the location of the safety factor result on specimen 4 which has the highest structural stiffness with 5942.31 N effective loading value. Design improvement is always carried out at the minimum value of safety factors that contribute the most stress and deformation under the loading. The improvement could be done by reviewing the design including changing or adding material to enhance the structural performance. In the case of specimen 4, the location of the minimum safety factor value is at the connector, and therefore the design review is not necessary as the minimum safety factor value is 3.82.

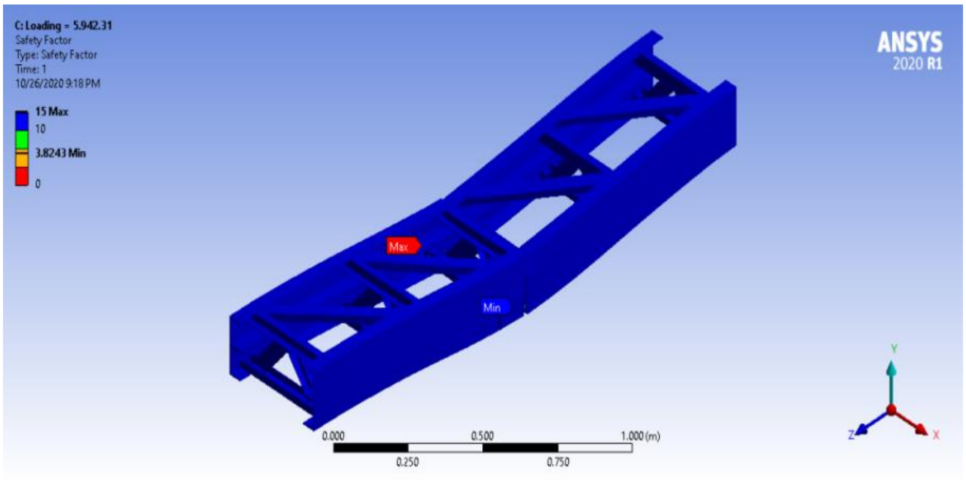

Figure 9 Minimum and maximum safety factor location

The minimum safety factor is 3.82 observed at the connector as Figure 10 illustrated with orange in colour with circular distribution around the hole. If the safety value is less than 2.0 then it is suggested to increase the thicknesses of the connector plate.

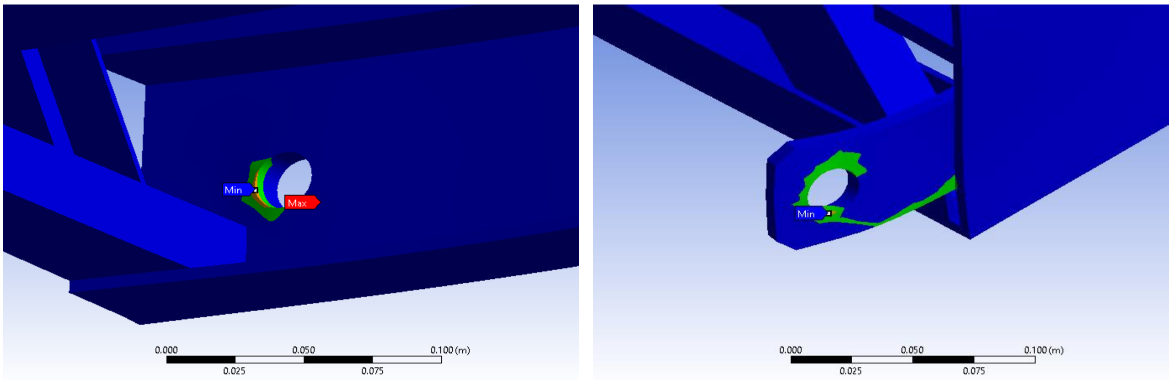

Figure 10 Minimum safety factor distribution in the model

CONCLUSION

This study concluded that the forest bridge with the modular concept is applicable to be used in accessing remote areas. This modular structure is safely used by the public if the minimum safety factor is higher than 2.0. In this study, the design safety factor 3.82 and the applied load factor is 1.75 that makes the total safety factor is 5.57. Structure design and material selection are important to allow this portable bridge to be assembled by the manpower. This study also concluded that applying stainless steel in this portable bridge design with the connectors show the structure is completely safe to be used by the public.

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EVALUATION OF WAVE SPEED ON MANGROVE STAND FOR COASTAL DEFENSE

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Mangrove forests play an essential role in tropical coastal environments by providing coastlines protection from erosion and extreme events. Mangrove stands could attenuate surge height and water flows velocity by obstructing the flow of water through the forest and at the same time absorbing the energy from the waves. The energy absorption strongly depends on forest density, the diameter of stems and roots, forest floor slope, bathymetry, and wave characteristics. This energy dissipation would lower the wave energy, reduce current turbidity and sediment erosion as well as promote sediment deposition which will contribute to shoreline stabilization. The role of mangroves in reducing the sea-waves velocity has been scientifically proved using drag analysis characterized by a tree drag value or bed friction coefficient. However, lack of understanding of how tree drag coefficients vary with tree morphology density and arrangement is a major source of uncertainty. This study aims to determine the drag coefficient value of the mangrove stilt roots system and how the wave speed could be reduced along the shoreline. This information would be very useful to the forest managers especially the Forestry Department of Peninsular Malaysia (FDPM) to effectively design and manage the mangrove forests for providing "natural protection" by applying the optimum tree density and width of tree plantings.

Keywords**:** Mangrove stands, natural protection, drag analysis, reforestation

INTRODUCTION

Mangroves grow in the upper intertidal zones of soft-sediment shores at tropical and subtropical latitudes (Minor et al. 2019). This ecosystem is considered as one of the most productive natural ecosystems in the world and has a well-established ecological, economic, and cultural importance (Jia et al. 2018) and support fisheries and biodiversity, protecting coastlines from erosion and extreme events (Minh et al. 2019). These natural defences are attractive because they are cost-effective solutions that provide multiple benefits, contributing to the community and ecological resilience (Shannon et al. 2016). Mangroves could attenuate the energy of tsunamis, cyclones, and storm surge and by reducing velocity on channel floodplain (Shan et al. 2019) and creating bed resistance by obstructing the flow of water through the forest (Dasgupta et al. 2019).

The role of mangroves in reducing the sea-waves velocity has been scientifically proven. For instance, six-year-old mangrove forests of 1.5 km wide will reduce open sea waves from 1 m high to 0.05 m when reaching the coast (Kathiresan & Rajendran 2005). Research indicates a belt of mangroves is capable of absorbing 30 to 40 per cent of the total force of a tsunami or typhoon and ensuing waves before they swirl over inhabited areas by the shore (COAST Trust 2001). Alongi (2008) estimates 50% declination in wave energy by going into 150 m of *Rhizophora*-dominated forest at high tide. Wave and storm-surge dampening by wetlands across a variety of storms that cause substantial drag (Dasgupta et al. 2019). Data on the density and width of trees planted and the diameter of trunks and roots, along with floor shape, bathymetry, and spectral features of waves could define the details and limits of mangroves as a protective function (Behera et al. 2018). Shoreline can be stabilized by reducing turbidity and velocity of water flow that caused erosion. Enhanced sediment deposition could strengthen the anchorage of the seedling on the ground and promotes tree growth. *Rhizophora mucronata* settles and dwells in the low to mid intertidal areas, and seedlings invest more in root growth further down the intertidal gradient (Minor et al. 2019).

About 35% of the world's mangrove forests disappeared during the last two decades even diligently protected. The distribution of mangroves stands still decreased significantly especially after the tsunami in 2004 (Jia et al. 2018). Sea level rise may be the other greatest threat to mangroves. Most mangroves affected had broken stems or were uprooted due to massive soil erosion or died due to prolonged inundation (Alongi 2008). However, the role of mangrove as a natural wave breaker may depend on mangrove vegetation, density of the forest, height of the tree, area of root and soil texture, wind speed, tidal wave height, coastal soil erosion level, sea level rise and other ecological disruptions. Wave and tidal activities change the coastal features and environment, coastal flooding and coastal erosion are serious forms of damage during severe storm events (Kumar 2015). In Malaysia, mangroves are mainly used for pole and charcoal production, however, constant pressure exerted by not only from natural events are responsible for its decline at a higher rate (Goessens et al. 2014) and this might decrease the effectiveness of the mangrove shoreline as an effective barrier against severe storm events.

The numerical model was capable to simulate fluid flow in an open channel in 2D and 3D analyses. The assessment of mangrove protection and the design is referred by a distributed drag characterized by a tree drag or bed friction coefficient. However, a lack of understanding of how tree drag coefficients vary with tree morphology density and arrangement is a major source of uncertainty (Minor et al. 2019). Numerical models on a tree drag would allow the mangrove forest manager to effectively design the mangrove restoration to maintain the function of "natural protection" to the coastal communities and assets (Behera et al. 2018).

MATERIALS AND METHODS

The selection of areas was based on storm-surge vulnerability and tidal characteristics (e.g., mud flat accretion/erosion and availability of adequate mangrove afforestation area in the foreshore of the coastal polders. This study specifically considers the mangrove species *Rhizophora*, which is one of the most popular species for mangrove planting and comprises approximately 90% of the world's mangrove species (Minor et al. 2019). A study plot size 10m X 10m was established at Lekir, Perak and above ground mangrove stilt root architecture was collected using systematic collection form. Information of diameter of tree trunks and roots, the height of roots from the ground level, the distance between trees and spacing of plantings were recorded.

Analysis of Computational Fluid Dynamics (CFD) was performed using ANSYS Fluent to determine the drag characteristic of the mangrove stilt root system and the velocity reduction along the plot length in the open channel model. Therefore, two different consecutive analyses were carried out using the Rectangular Open Channel system. The channel size for single mangrove aerial root drag analysis applied 2m height and 10.2 m width and 10.2 m length, while the channel size for velocity reduction analysis applied 2m height, 6 m width and 14 m length. The seawater properties are defined to 1023.387 kg/m3 density and 0.000959 $kgm^{-1}s^{-1}$ viscosity. The analysis applying water velocity in a mangrove swamp, the mean magnitude of the water velocity is around 10 cm/s (Minor et al. 2019). Shan et al. (2019) also applied 10 cm/s velocity to the model velocity, which satisfied Froude number similarity with the real field scale of tidal flow and storm surge, 20–50 cm/s.

Reynolds number for mangrove root drag analysis and velocity reduction is 356,852 and 320,142 consecutively. Both Reynolds number shows that the analyses were categorized in turbulence flow. In this study, the standard k-epsilon turbulent viscous model was applied during the simulation with the SIMPLEC solution type. The analysis was carried out using pressure-based type analysis with absolute velocity formulation and steady time series. The analysis of the drag coefficient in the mangrove stilt root system (Figure 1) was done by calculating the drag value of slices at 0.25 m interval height of mangrove root (Figure 2). All 2D specimens were meshed applying the triangular method with 0.025 m element size.

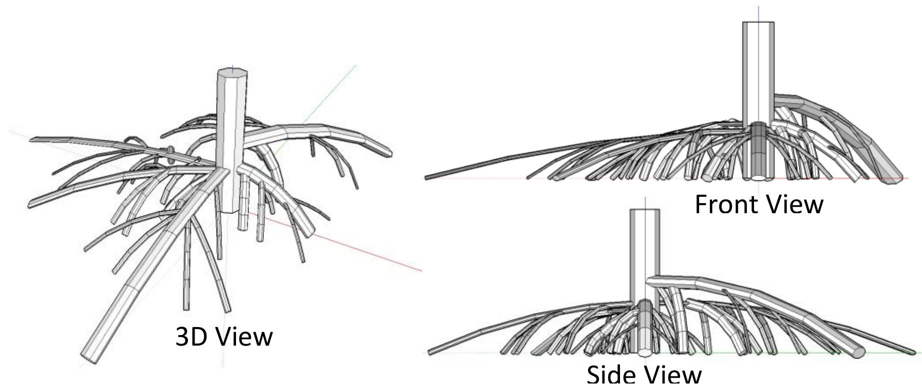

Figure 1 Mangrove aerial root tree model

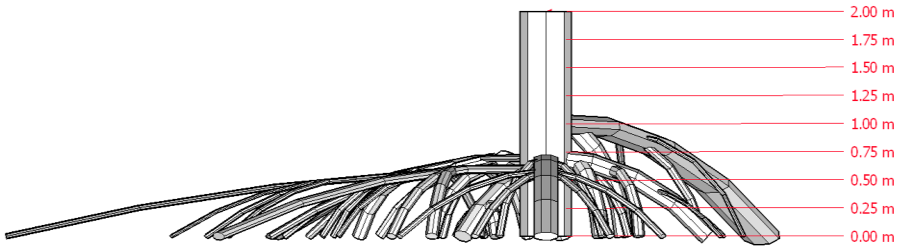

Figure 2 Slices of root at different height

Six specimens have been identified to be analysed in the mangrove stilt root system. It was observed that the effective result analysis for drag coefficient is from 0m till 1.25 m. This height range consists of a variation mangrove root cross-section. The cross-sections of specimen slices from 1.25 m to 2.00 m are similar therefore the drag result was represented by specimen slice at 1.25 m height. Therefore 6 slices were analysed in this specific mangrove stilt root model (Figure 3). The result of cross-section for Slice 1 (S1), Slice 2 (S2), Slice 3 (S3), Slice 4 (S4), Slice 5 (S5) and Slice 6 (S6) is 0.46 m^2, 0.81 m^2, 1.20 m^2, 0.40 m^2, 0.56 m^2 and 0.16 m^2 consecutively.

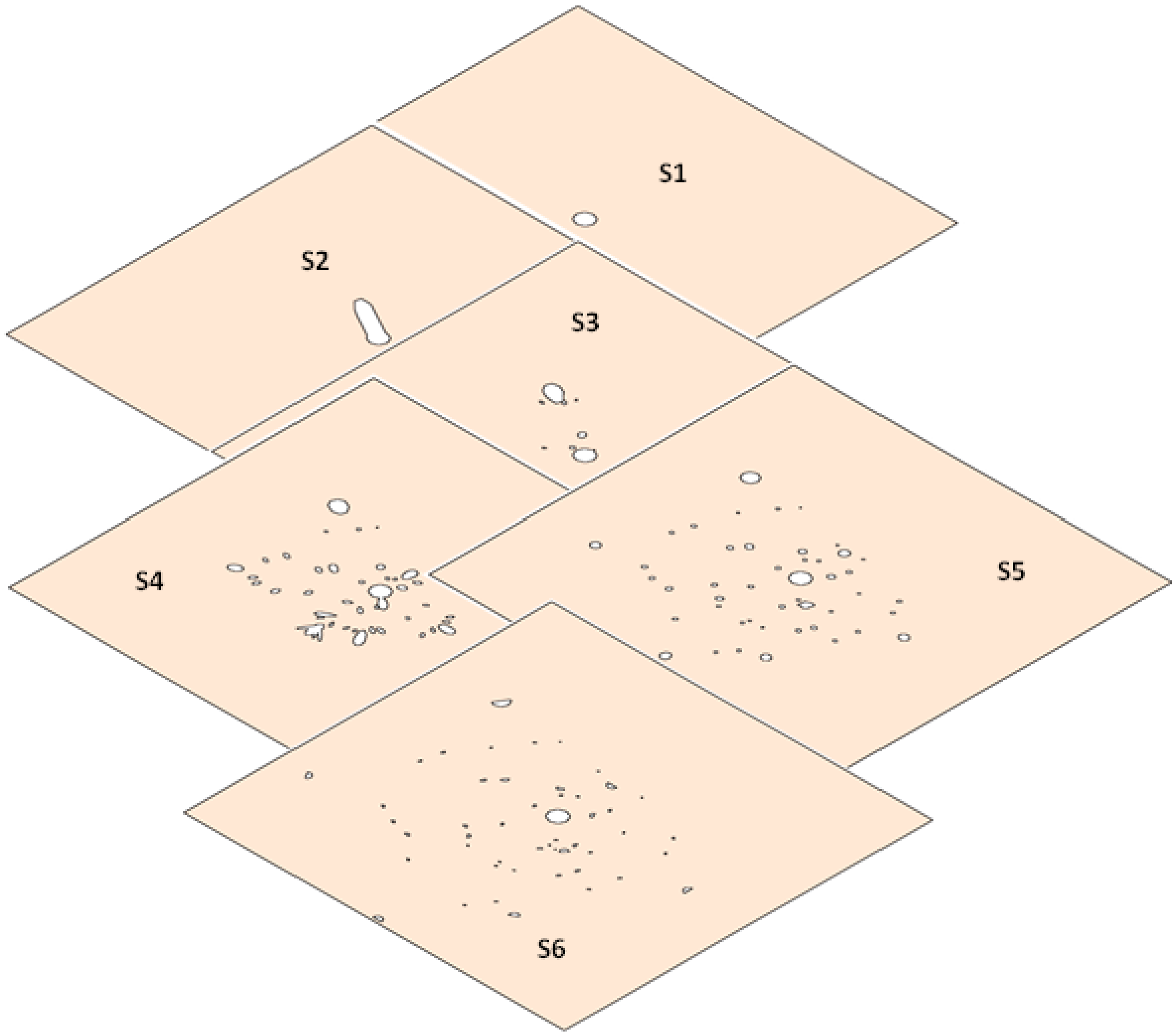

Figure 3 Specimen slices in root system

The maximum drag coefficient of the mangrove aerial root system could be determined from the first analysis. The height of the maximum drag coefficient resulted from the first analysis was used as the main reference for slice height for velocity reduction analysis. In the velocity reduction analysis, 5 models were arranged in-line distribution with spacing of 2.00 m between each tree. This could represent the density of the mangrove stand up to 2500 trees/ha which could be categorized as high-density mangrove stand (Figure 4). The specimen for velocity reduction analysis was prepared based on the highest drag analysis result. Analysis of velocity fluctuation in the specimen was carried out on the analysis path with the same parameter set up as in the previous analysis (Figure 5).

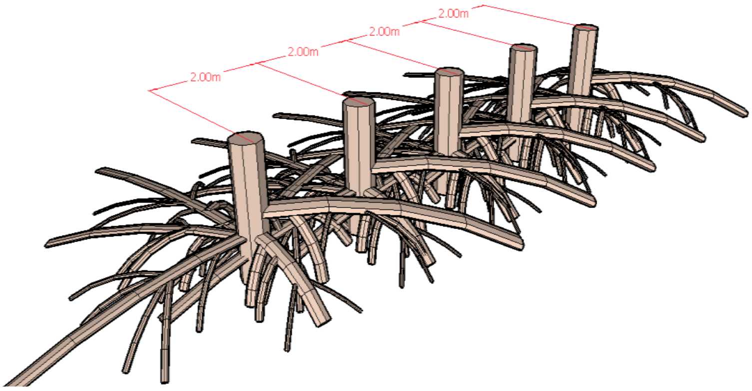

Figure 4 Model for velocity reduction in-line distribution

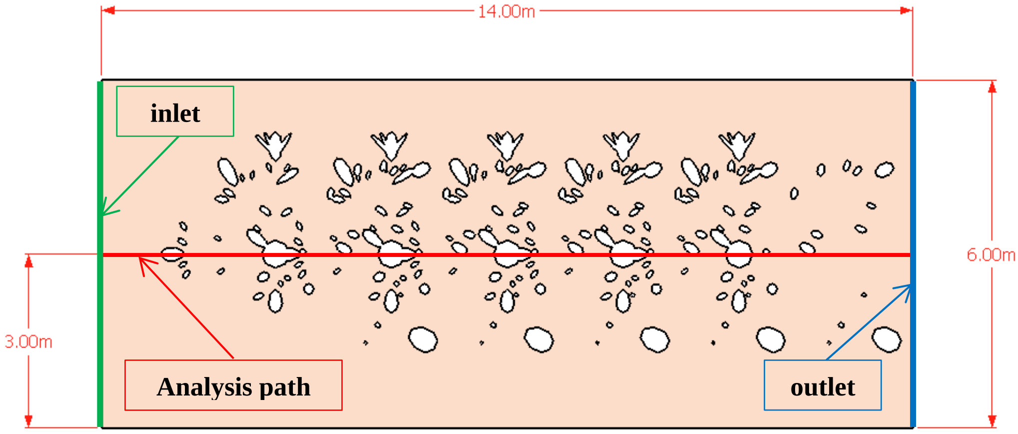

Figure 5 Specimen for velocity reduction in-line distribution

RESULTS AND DISCUSSION

Analysis of drag coefficient in mangrove aerial root system uses 6 slices extracted from the tree model. It was observed that the highest cross section area from the model is the third slice at 0.5 m from the ground level is 1.2 m^2. The lowest cross section area of the specimen slices is 0.16 m^2 which is the highest slice from the ground level at 1.25 m. This cross section is also a mangrove bole diameter. In terms of drag coefficient, the highest drag value is from the third slice with 7.0493 followed by the first and second slice which is 5.6995 and 4.8354 consecutively. The lowest drag value is observed at the lowest cross section which is on the sixth slice at 1.25 m height with 0.1488. The average cross section and drag value for this specific tree model referring to 6 slices of the specimen is 0.598 m^2 and 3.4249 consecutively. Figure 6 also shows that the effective drag force acting on the water flow is from slices 1, 2 and 3 that are the bottom half of the mangrove aerial root system. In the velocity reduction analysis, the height of the slice with the highest drag value was applied for preparing the specimen. Figure 7 shows the velocity behaviour of water flows from the inlet to the outlet in the fluid domain. Analysis was focused on the analysis path at the centre of the specimen through the fluid domain. Each cross section of the tree model on the specimen at this slice height would influence the velocity flow at the middle of the fluid domain. Therefore, this study assumes applying a single path for analysis of velocity reduction in the fluid domain is applicable.

Table 2 Drag coefficient in mangrove aerial root system

Slice	Height (m)	Cross section (m^2)	Drag Coefficient
S1	0.00	0.460	5.6995
S2	0.25	0.810	4.8354
S3	0.50	1.200	7.0493
S4	0.75	0.400	1.4823
S5	1.00	0.560	1.3339
S6	1.25	0.160	0.1488
Max.		1.200	7.0493
Min.		0.160	0.1488
Average		0.598	3.4249

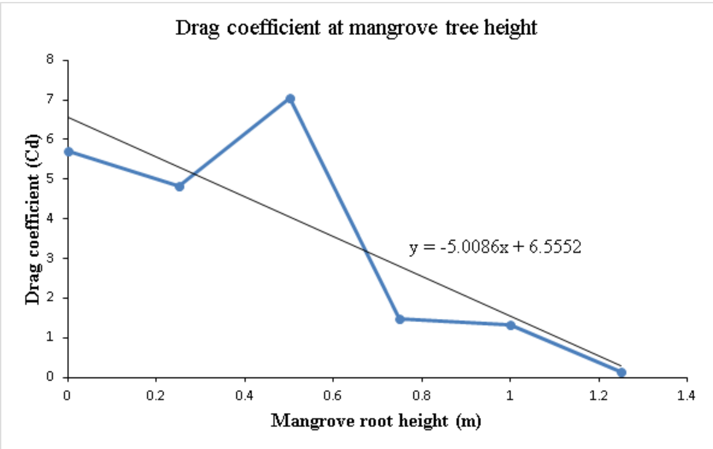

Figure 6 Drag coefficient result in mangrove aerial root system

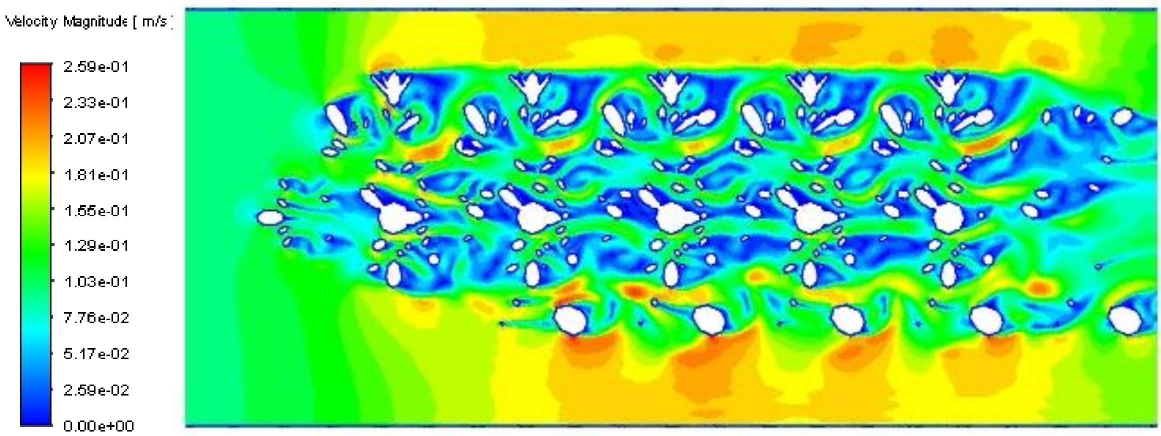

Figure 7 Behavior of velocity contour in mangrove in-line distribution

Meshing with 0.025 m size with the triangular method creates 134564 nodes and 263087 elements on the specimen. The path line at the centre uses 683 points nodes that contain velocity information of the analysis. Velocity on path line based in nodes was extracted and plotted into a graph (Figure 8). The trend line was created from the fluctuation of velocity on that extracted node. It is expected the width of mangrove forest from the shoreline is represented by this equation. The inlet velocity was set to 0.1 m/s and the reduction in water velocity through the tree models and expected to be disseminated at 29.125 m of 2500 trees/ha density of mangrove stand with the in-line distribution. This width is calculated from the equation when the Y-axis value is set to zero. This width 29.125 m is the proposed span for certain mangrove forests from the shoreline to act as a barrier to the storm and tidal surge waves. The selection highest drag value for preparing specimen slice indicates that 29.125 m to be the minimum width of mangrove stand.

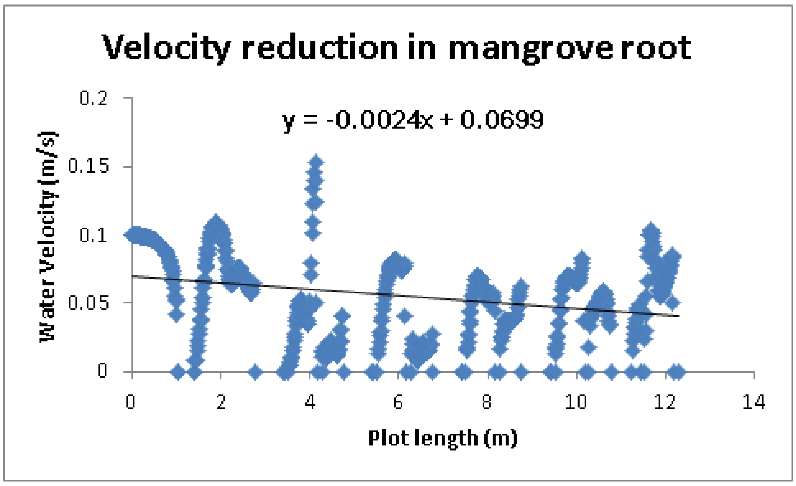

Figure 8 Velocity reduction in-line mangrove distribution

CONCLUSION

This study concluded that drag analysis could be used to analyse the drag distributions in mangrove trees and possibilities to reduce water flow in mangrove stands. An effective drag force is observed at the bottom half of the mangrove stilt root system. The increase in height of mangrove trees shows the decrease in drag value and also the tree model cross section. The mangrove stand possibly reduces the wave velocity and water flows. It is expected to totally disseminate 0.1 m/s velocity of water flow is 29.125 m minimum width of mangrove forest from the shoreline at 2500 trees/ha density. However, the drag effect on the mangrove tree model should be further studied by using actual water velocity and simulating the drag analysis of the stilt root system in three dimensions. The number of tree models in the targeted area for reforestation should be increased to accurately suggest the planting width to create natural protection to the shoreline.

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ENHANCEMENT OF THE CLEARING HOUSE MECHANISM FOR BIOLOGICAL DIVERSITY FOR MALAYSIA (PHASE II)

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Biodiversity encompasses the variability among living organisms. Among 1.75 million identified species in Malaysia, scientists estimated that the actual number is about 13 million species. Malaysia Clearing House Mechanism for Biological Diversity (MyCHM) or currently known as Malaysia Biodiversity Information System (MyBIS) is a website developed to collate information from a variety of sources and disseminate information to the public. The system was developed and maintained by Forest Research Institute Malaysia (FRIM) since 2005 and is currently owned by the Ministry of Energy and Natural Resources (KeTSA). The rebranding of MyCHM started in 2015 with the aim to enhance its function as a one-stop repository for biodiversity, provide statistical analysis of biodiversity data and conduct Communication, Education and Public Awareness (CEPA) activities to create public awareness of biodiversity and environmental issues. Within RMK11, we have collaborated with various agencies in the Specimen Module and Toxinology Module, published seven coffee table books, and newsletters, as well as organised seminars, and workshops, and shared fun facts or major international biodiversity events on social media. Furthermore, the data provided in the system will be able to help the public, various agencies, stakeholders, and policymakers for better implementation of the national biodiversity strategies and action plans.

Keywords: Clearing house mechanism, MyBIS, biological diversity, one-stop repository

INTRODUCTION

The Clearing House Mechanism for Biological Diversity or currently known as Malaysia Biodiversity Information System (MyBIS) is a website developed and maintained by Forest Research Institute Malaysia (FRIM) since 2005 and currently owned by Ministry of Energy and Natural Resources (KeTSA). Fifteen years in FRIM had seen that the website transformed into three phases (Hamidah & Yasser 2016).

The first phase was the Flora of Peninsular Malaysia (FPMO) website which focused on website and interactive database of the flora of Peninsular Malaysia. The FPMO was launched on 28th June 2005 by YBhg. Dato’ Sazmi bin Miah, the Parliamentary Secretary of the Ministry of Natural Resources and Environment (NRE) during the Seminar on the Status of Biological Diversity in Malaysia and the Workshop on Threat Assessment of Plant Species in Malaysia.

The second phase commenced in 2010 when Malaysia committed to the Convention on Biological Diversity to undertake the role of Clearing-House Mechanism National Focal Point (CHM-NFP). The FPMO website was merged to a new website to accommodate the fauna information. The website was known as the Malaysia Biodiversity Clearing House Mechanism (MyCHM) and can be accessed via www.chm.gov.my. The merger has allowed MyCHM to become a fully functional one-stop repository for Malaysia's biodiversity website. MyCHM was officially launched by the Minister Dato Sri Douglas Uggah Embas during the opening ceremony of the National Biodiversity Centre Stakeholder Consultation Workshop on 15 May 2012.

The rebranding of MyCHM started in 2015 with the aim to enhance its function as a one-stop repository for biodiversity, searchable databases on flora and fauna, protected areas, Specimen Collection Center and publications related to biodiversity; provide statistical analysis of biodiversity data; conduct Communication, Education, and Public Awareness (CEPA) activities to create public awareness on biodiversity and environmental issues (Nurfarhana & Tan 2021). MyBIS website can be accessed via www.mybis.gov.my.

MATERIALS AND METHODS

MyBIS website was developed using Open Source technology such as PHP 8.08 programming for Content Management System development and MySQL 5.7.34 for database management. Development of web interface was made using Bootstrap 3.0 framework that supports a responsive interface for desktop, tablet, and mobile display, in large or small resolution for best view by using the latest browser version of Google Chrome, Mozilla Firefox, Microsoft Edge and Safari. Other than that, MyBIS used Darwin Core (DwC) as an extension for data sharing.

The restructuring of MyBIS introduced four main modules, namely Discover (searching information through sorting by species, specimen, photos, and structures), Explore (provides information on protected areas in Malaysia including the history and geographical of Malaysia), Analysis (covers dataset, maps and timeline records in MyBIS) and References (covers the directory of biodiversity experts and a library for biodiversity-related literature and glossary).

The data were entered manually since 2014 by MyBIS administrator, practical students and also the expert who manages for each specimen collection centres. The biodiversity information in the database is collated from various types of publications such as journals, articles, books, and others. Then the data will be extracted into the system. The user manual has also been prepared as a guide for new registered users to enter the data into the MyBIS.

Monthly reports on the outcome of the total data entry, CEPA programmes, and dissemination of biodiversity information on social media such as Facebook and Twitter, and total publication were submitted to KeTSA.

Several capacity building workshops were conducted to train users on the tools and methods of data input. MyBIS is a platform for the agencies to store specimen data and at the same time contributed to the biodiversity data with the cooperation of FRIM staff and other agencies. The contribution from various agencies will increase the data richness and therefore will strengthen the quality of the system.

CEPA Activities

Communication, Education and Public Awareness (CEPA) is a term introduced for the work program of the Convention of Biological Diversity (CBD) on a cross cutting theme. It allows biodiversity specialists or experts to share and exchange expertise across sectors. It also aims to reduce the loss of biodiversity, conserve it and implement the National Biodiversity Strategies and Action Plans (NBSAPs), where collaboration and cooperation of individuals, organisations, and groups in society to act on the drivers for its loss (Anon 2022). The MyBIS team works together with government agencies, universities, corporates, and NGO in order to spread information, knowledge and values of biodiversity in Malaysia. Surveys were conducted to determine the effectiveness of the CEPA activities.

MyBIS Telegram Bot

In 2018, improvements were made by introducing new modules and telegram autobot smart search features (Figure 1). The steps to search species through MyBIS Bot in Telegram are:

1. Download the telegram apps via Google Play Store (for Android users) or Apple App Store (for iOS or iPhone users)
2. Search "mybisgovmy" and click "Start"
3. Type a scientific name, keyword, common name or MyBIS SSN and click "Send".
4. Click on the link to go directly to the species profile in MyBIS.
5. The profile species will appear in MyBIS website for more information.

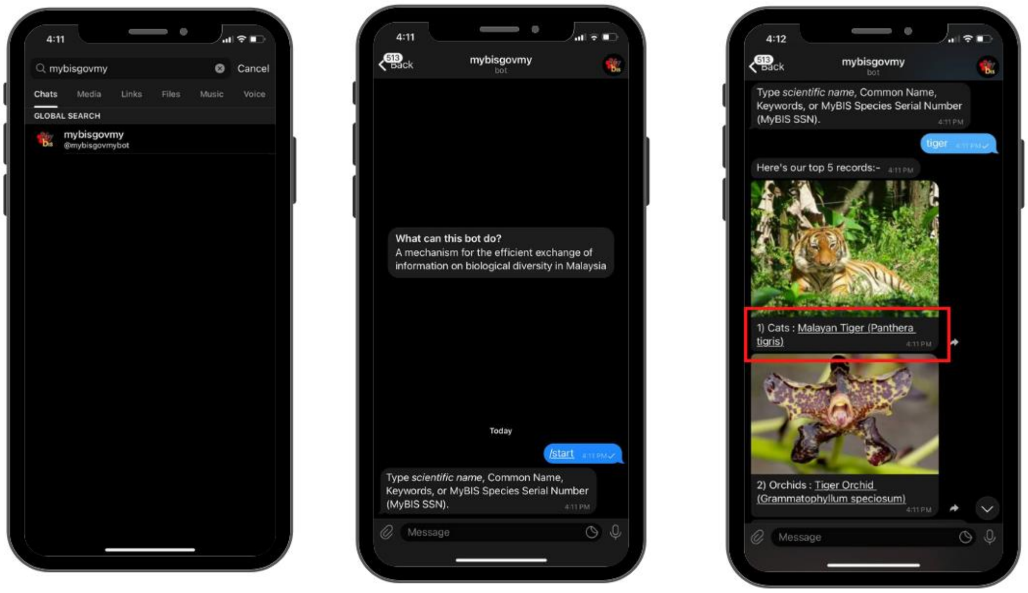


Figure 1 Telegram bot search function

Google Analytics

Google Analytics was used to get the information on the users' habits, top country who uses MyBIS website, minutes per session or time used when browsing MyBIS website.

RESULTS AND DISCUSSION

Currently, MyBIS provides more than 47,000 species of plants, animals, and fungi with more than 10,000 attractive photos, more than 200 monthly newsletters, 4,000 references and literature records and has a registered number of 582 biodiversity-related experts. In early 2016, MyBIS has embarked on the data integration of collections of specimens into a single national biodiversity collection database. To date, 25 Specimen Collection Centres are registered with MyBIS and use MyBIS as the online system to manage specimen records. These centres are presented in Table 1. Until 31 December 2021, there are about 129,956 specimens recorded in the MyBIS Specimen Module.

The public can now use the MyBIS website to search for species of interest, photos or galleries, habitat assessments; read monthly published newsletter; and find various references that are available for downloading (Figure 2 & 3).

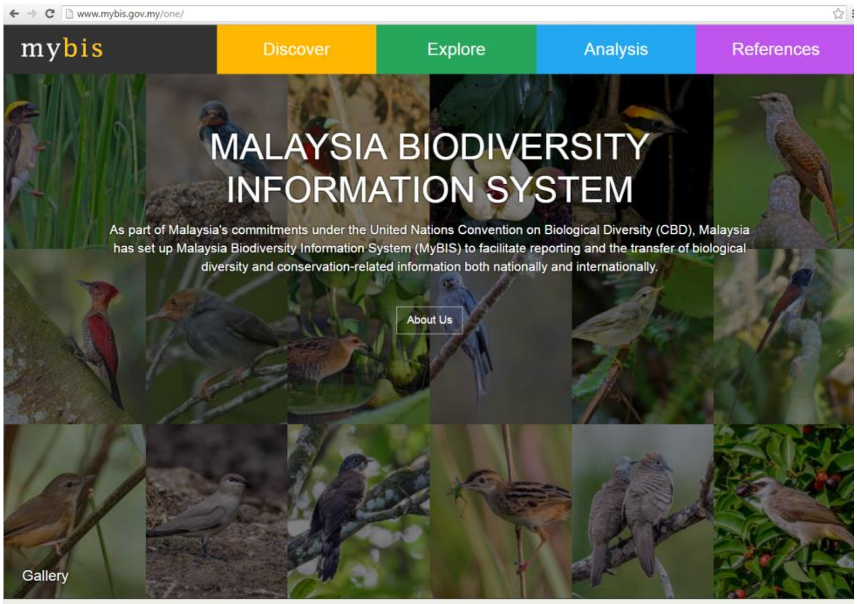


Figure 2 Main page of MyBIS website: Access to all modules, newsletter, and publications

Table 1 Specimen Module with registered Specimen Collection Centres (updated up to 31 December 2021)

No	Agency/ University/ Institute	Title of Collection Centre	Total
1	**Department of Wildlife and National Parks (PERHILITAN)**	PERHILITAN Wildlife Collection	12,096
2	**Forest Research Institute Malaysia (FRIM)**	FRIM Entomological Reference Collection	5,121
		Wood Collection	4,220
		FRIM Herbarium Collection	326
3	**Institute for Medical Research (IMR)**	IMR Collection	9,447
4	**Natural History Museum**	Muzium Alam Semula Jadi Collection	10,007
5	**University of Malaya**	Herbarium Collection	9,006
		Zoological Collection	15,999
6	**Universiti Kebangsaan Malaysia (UKM)**	Centre for Insect Systematics	30,601
		Plant Collection of Taman Paku Pakis UKM	1,203
		Muzium Zoologi UKM	5,083
7	**Universiti Malaysia Terengganu (UMT)**	Marine Collection	8,625
8	**Universiti Sains Malaysia**	USM Herbarium Collection	3,064
		USM Zoological Collection	2,204
		CEMACS Marine Reference Collection	0
9	**Perbadanan Putrajaya**	Koleksi Tumbuhan Taman Botani Putrajaya	2,125
		Koleksi Tumbuhan Taman Rimba Alam Putrajaya	315
10	**Universiti Malaysia Sabah (Mula berdaftar pada April 2019)**	Marine Reference Collection	1,373
		BORNEENSIS Institute for Tropical Biology & Conservation	2,637
11	**Natural History Museum London (Mula berdaftar pada Okt 2019)**	Malaysian Iconic Wallace Species	1,917
		Malaysian Collection	1,004
12	**Iskandar Regional Development Authority (IRDA)**		
	-Perbadanan Taman Negara Johor (PTNJ)	Johor National Park	172
	-Kelab Alami Mukim Tanjung Kupang	Kelab Alami Collection	256
13	**Dewan Bandaraya Kuala Lumpur (DBKL) (Mula berdaftar pada Mac 2020)**	Koleksi Tumbuhan Taman Botani Perdana Kuala Lumpur	2,000
14	**Universiti Malaysia Kelantan (UMK) (Mula berdaftar pada Nov 2020)**	Muzium Fakulti Sains Bumi, Universiti Malaysia Kelantan	1,155
		Total Overall	129,956

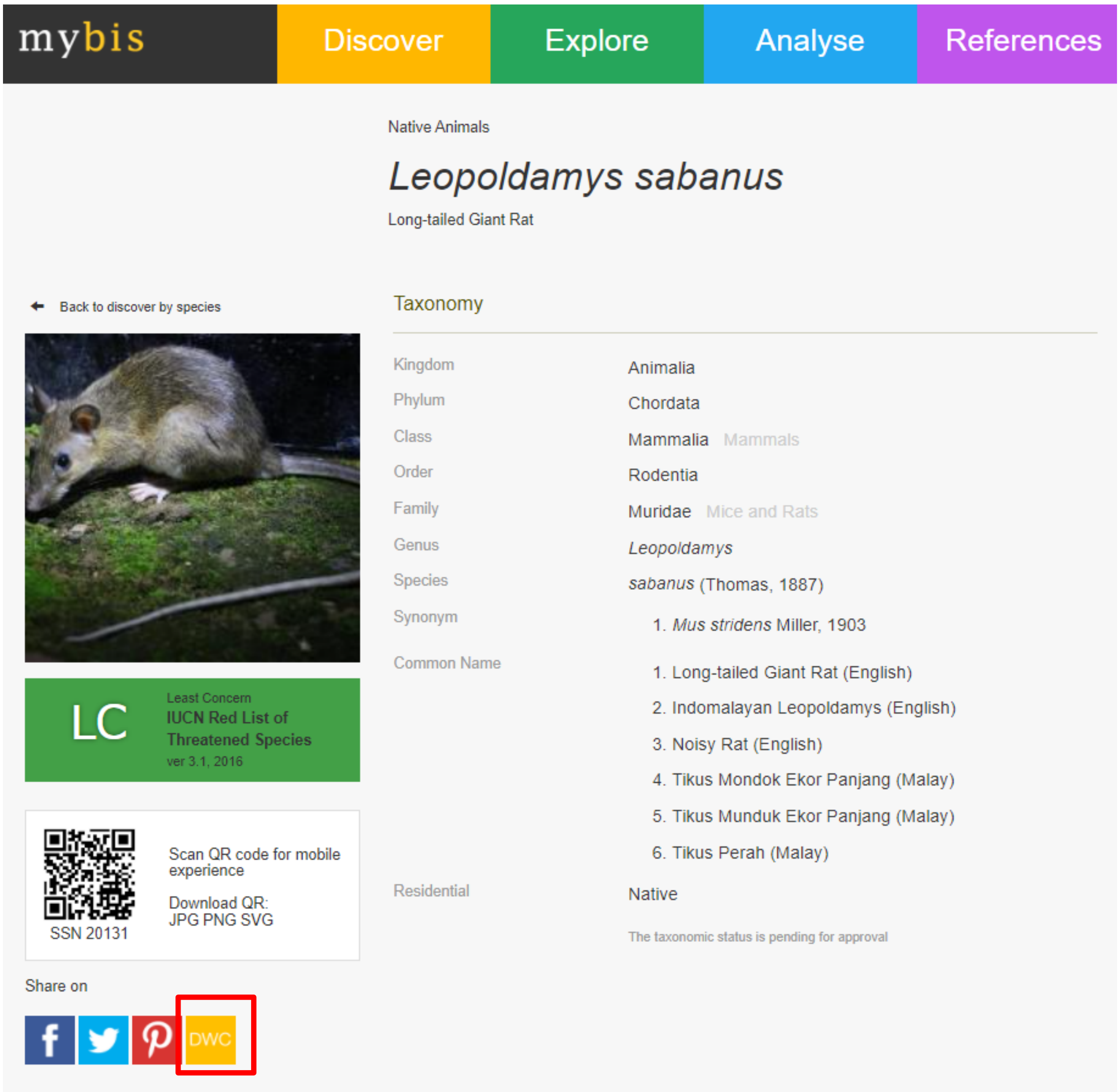
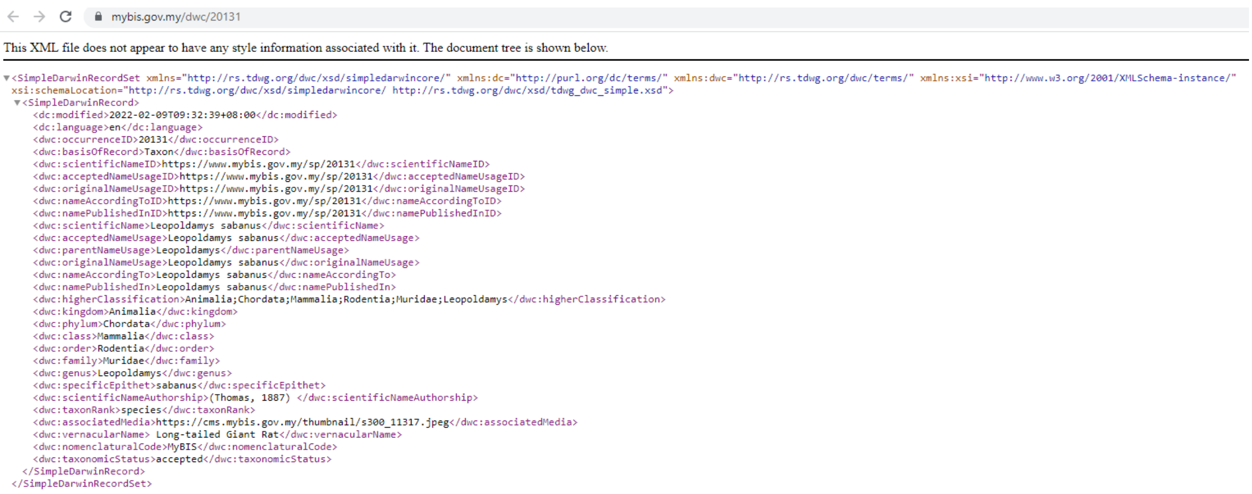


Figure 3 The interface for Profile Species (In picture: Long-tailed Giant Rat or *Leopoldamys sabanus*) and the Darwin Core (DwC) as an extension for data sharing


mybis.gov.my/dwc/20131

This XML file does not appear to have any style information associated with it. The document tree is shown below.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    <dwc:order>Rodentia</dwc:order>
    <dwc:family>Muridae</dwc:family>
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    <dwc:vernacularName> Long-tailed Giant Rat</dwc:vernacularName>
    <dwc:nomenclaturalCode>MyBIS</dwc:nomenclaturalCode>
    <dwc:taxonomicStatus>accepted</dwc:taxonomicStatus>
  </SimpleDarwinRecord>
</SimpleDarwinRecordSet>
```


Figure 4 The Darwin Core XML file for each species

Darwin Core is a standard maintained by the Darwin Core Maintenance Interest Group. It includes a glossary of terms (in other contexts these might be called properties, elements, fields, columns, attributes, or concepts) intended to facilitate the sharing of information about biological diversity by providing identifiers, labels, and definitions (Figure 4). Darwin Core is primarily based on taxa, their occurrence in nature as documented by observations, specimens, samples, and related information (Darwin Core Maintenance Group, 2021). It can be defined at any species in MyBIS.

In 2018, the introduction of a telegram bot for MyBIS website allowed users to search for the common name, scientific names or any SSN number for each species in a shorter time. SSN stands for Species Serial Number, and it is a unique identifying number for every species. This serial number enables a user to search for a particular species quickly without scanning the QR. This can be done by changing "xxxxx" with SSN in the address bar/URL https://mybis.gov.my/sp/xxxxx. For example, SSN 20131 is the profile species webpage for Long-tailed Giant Rat.

Every month, at least one newsletter in MyBIS website (https://www.mybis.gov.my/one/article.php?menu=36) was published, highlighting species for scientific reading to enhance the knowledge on biodiversity. The information provided in the newsletter is very interesting and useful especially to the nature lovers. Since 2016, several coffee table books have been published with the collaboration with universities and other agencies, such as Ancient Creatures: Dragonflies and Damselflies of Malaysia, Bird of Malaysia, Frogs and Toads of Malaysia: Malaysia Biodiversity Information System (MyBIS), Land Snakes of Medical Significant of in Malaysia, Mangrove Flora of Malaysia, Land Snakes of Malaysia, Bats of Malaysia, and Fishes of North Selangor Pear Swamp Forest (Figure 5). In near future, we are planning to publish Marine Fish in Kuantan, Monkey of Peninsular Malaysia, An Introduction to the Land Snails and Slugs in Malaysia and others. These electronic books can be downloaded from MyBIS website or via https://www.mybis.gov.my/one/publication.php?menu=27.

CHM Award

MyBIS went online in April 2016 and was officially launched on 21 September 2017 by NRE's Minister YB Dato Sri Dr. Wan Junaidi bin Tuanku Jaafar. On 9 December 2016, Malaysia received the CHM Gold Award at the Thirteenth Meeting of the CoP to CBD (COP13) held in Cancun, Mexico (Mohmod et al. 2020) (Figure 6). This recognition shows that Malaysia is making significance progress in the development of its national CHM, and continued support from all participating agencies, partners and the Ministry is very crucial.

In 2018, MyBIS team has successfully maintained the system and awarded for the Certificate of Achievement for the existing CHM during COP14 in Sharm El Sheik, Egypt, which has held from 17 to 29 November 2018 (Figure 7).

Figure 5 Book and ebook publication of MyBIS in collaboration with various agencies from 2016 – 2021

Figure 6 The trophy and Gold Award certificate received by the Government of Malaysia

Figure 7 Certificate of Achievement for the existing CHM during COP14 in Sharm El Sheikh, Egypt

Malaysia Book of Record

The recognition of 'Largest Online Records on Biodiversity Information - 47,000 species' in Malaysia Book of Records (MBR) was awarded to the Malaysia Biodiversity Information System - MyBIS operated by FRIM and the Ministry of Energy and Natural Resources (KeTSA). This event was held on 28 August 2020 (Figure 8).

Figure 8 The MBR Ceremony was held at FRIM MBR Corner. From left: Dr Lillian Chua, Datuk Dr Abd Latif Mohmod, Christopher Wong Hong Wai, & Tan Kok Kiat

Starting from 2016, Malaysia is the top countries (Figure 9) who visited MyBIS website with 3-4 minutes per session, followed by Indonesia (34,335 visitors) and United States (27,730 visitors). There is an increasing trend of using MyBIS website (Figure 10) as result of CEPA activities and social media promotion of biodiversity-related information to government agencies, corporations, non-governmental organisations, and the public.

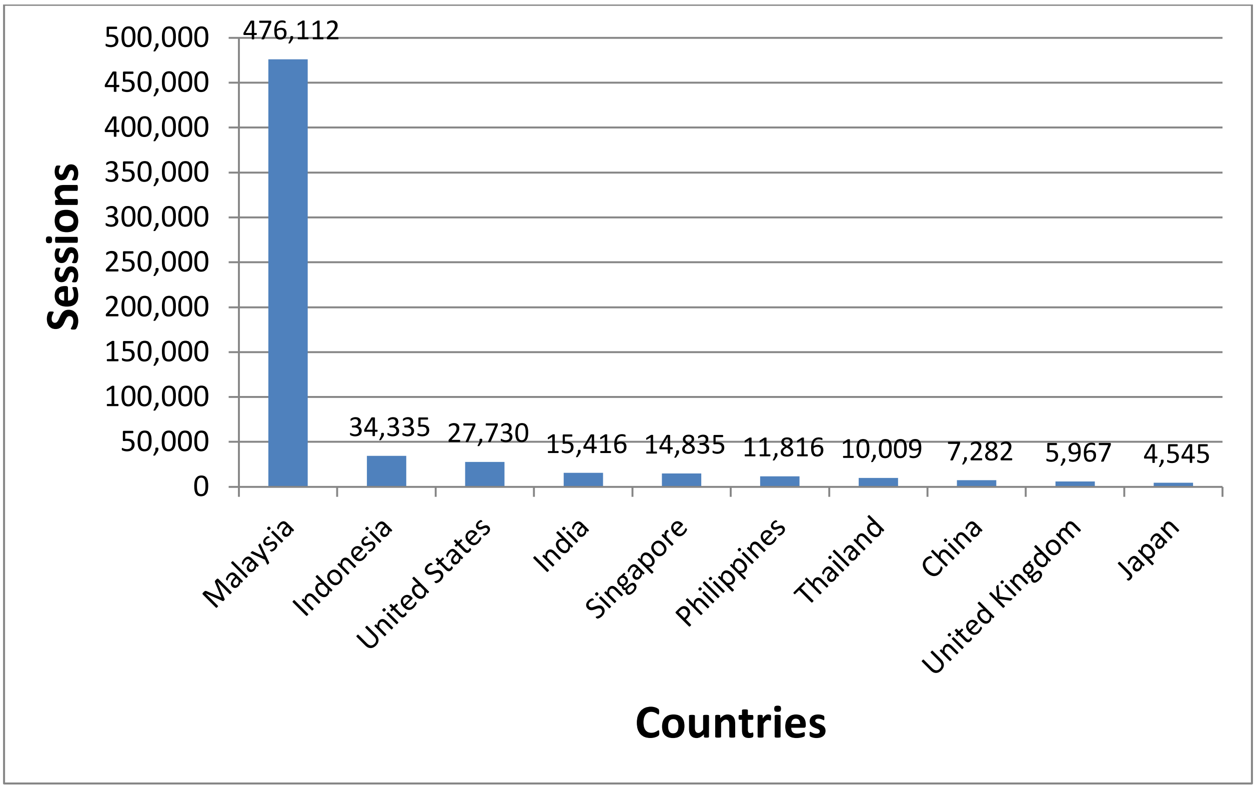


Figure 9 Top 10 Countries visited MyBIS website (based on Google Analytics 2022)

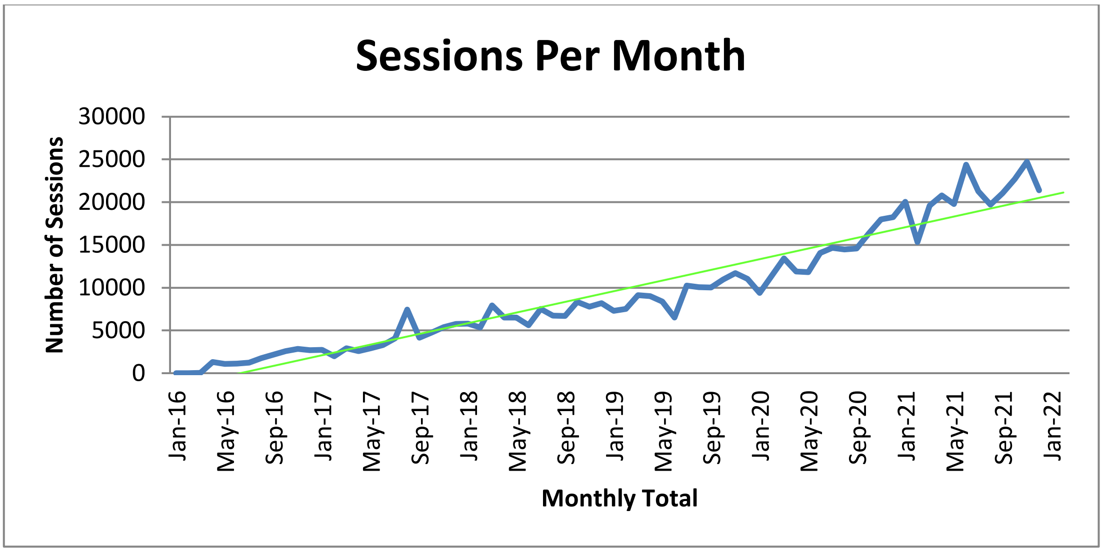


Figure 10 Number of sessions per month visited MyBIS website for every 3-4 minutes

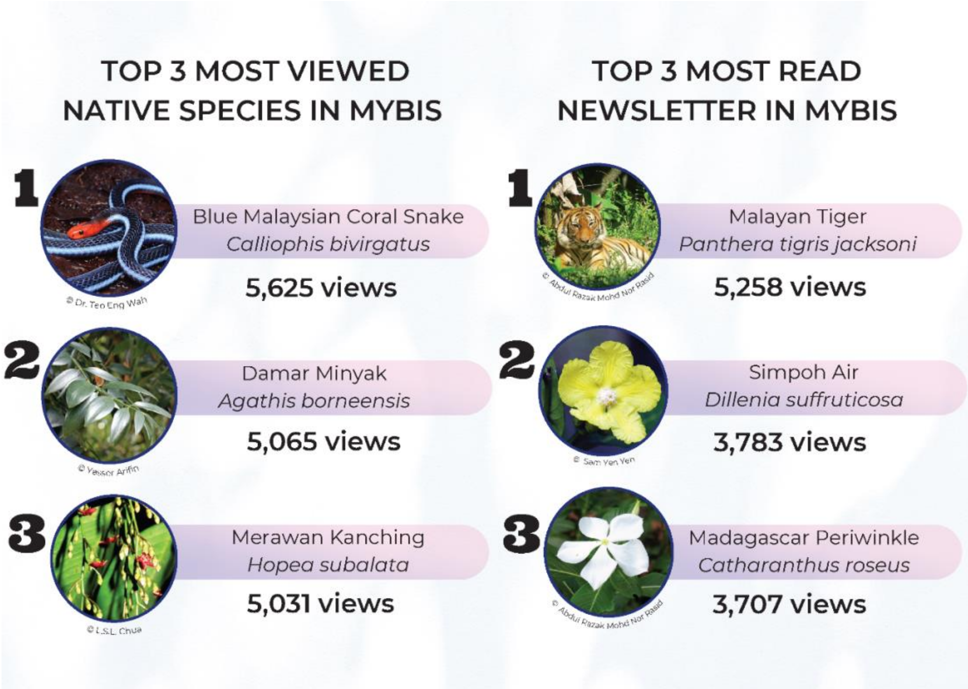


Figure 11 The top 3 most viewed native species in MyBIS and top 3 most read newsletter in MyBIS (based on the statistical analysis from MyBIS website) (Tan et al. 2022)

Until 31 December 2021, the top 3 most viewed native species in MyBIS are the Blue Malaysia Coral Snake, "damar minyak" and "merawan kanching". The Blue Malaysian Coral Snake is the most viewed species may be due to the venomous and the attractive colour of this snake. Meanwhile, the top 3 most read newsletters in MyBIS are Malayan tiger, "simpoh air" and Madagascar periwinkle (Figure 11). The Malayan tiger newsletter is the most read newsletter could be due to its conservation status in Malaysia, the trend of the number of Malayan tigers is dwindling in Malaysia and the icon as well as the symbol for the Coat of Arms of the country.

67 CEPA activities had been conducted from 2016-2021 in order to spread about MyBIS website and biodiversity-related information (Figure 12). Promotion from educational workshops, seminars, webinars, exhibitions and interaction between government agencies, universities, NGO's and the public were done for these purposes. Fun facts about biodiversity, flora and fauna are also spread through social media. From the survey that we have done, most of them clear are about the definition and the importance of the biodiversity around them.

From one of the surveys conducted in conjunction with World Environment Day in 2016, most of the citizens are aware and understand the definition and the importance of the biodiversity. A total of 145 citizens were participated and responded to the survey, in which 23 of them were males (15.86%) and 122 were females (84.14%) (Figure 13). The participants' occupation includes students, government, private sector, self-employed and others (Figure 14).

Figure 12 CEPA Activities are being undertaken in order to increase public awareness on biodiversity

We found that only 30 participants knew and were aware of the biodiversity celebration day whereas 95 of them do not know the celebration date and the rest were not sure. On the question of knowledge about the illegal wildlife trade had the majority (133 participants) ticked “true” that the illegal wildlife trade involves live animals and plants, or a diverse range of products needed or prized by humans, while three participants chose “No”, and the other nine participants were “Not Sure”.

Next question was on the product made from protected animals will have any effect to the ecosystem's balance. About 131 participants (90.34%) knew that the loss of protected animals will cause unbalance to the ecosystem. The question whether the fine and/or jail will be imposed if catch, preserve or sell protected animals without license was also included and majority of the participants (131 people; 90.34%) knew the type of fine that will be charged for the offender.

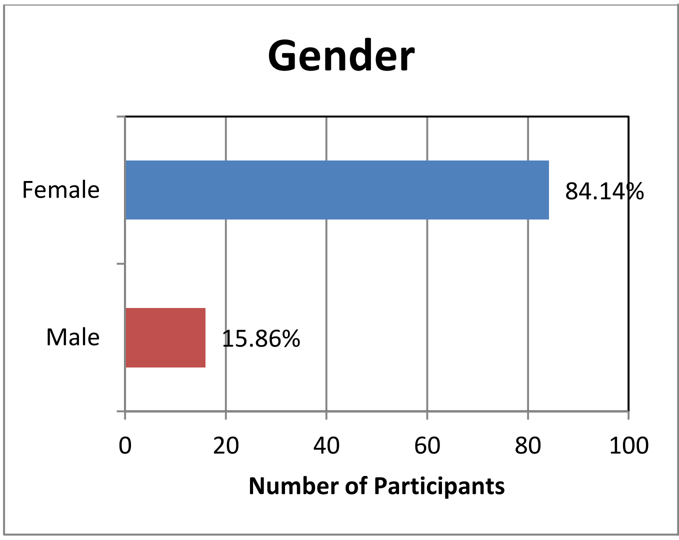


Figure 13 Gender of participants

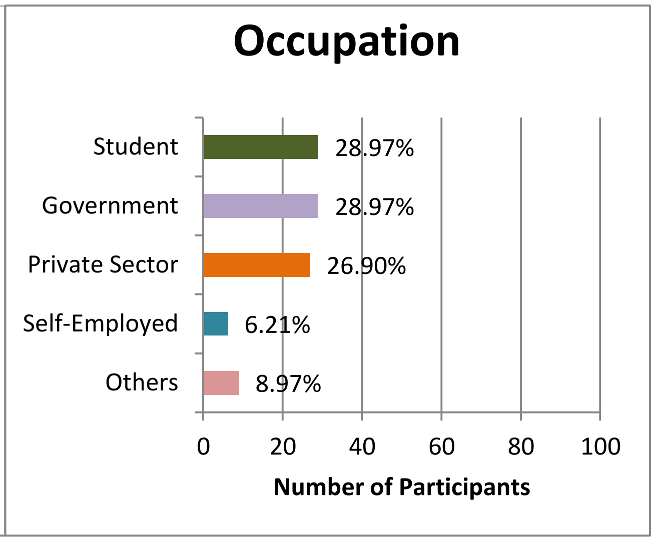
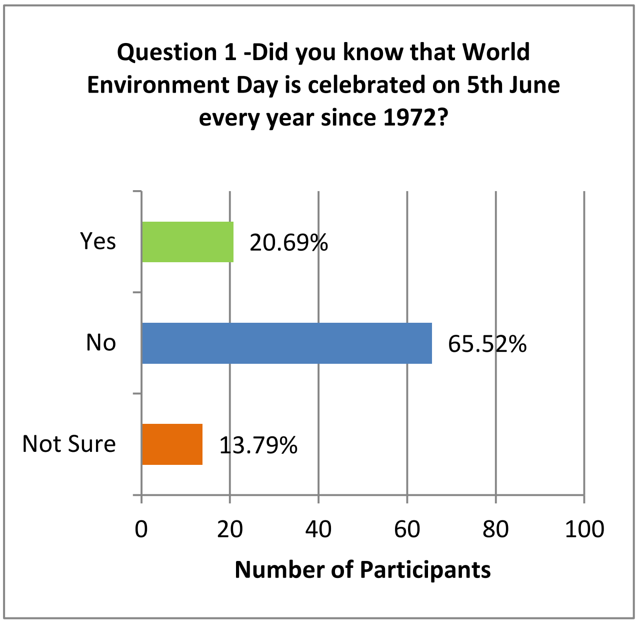
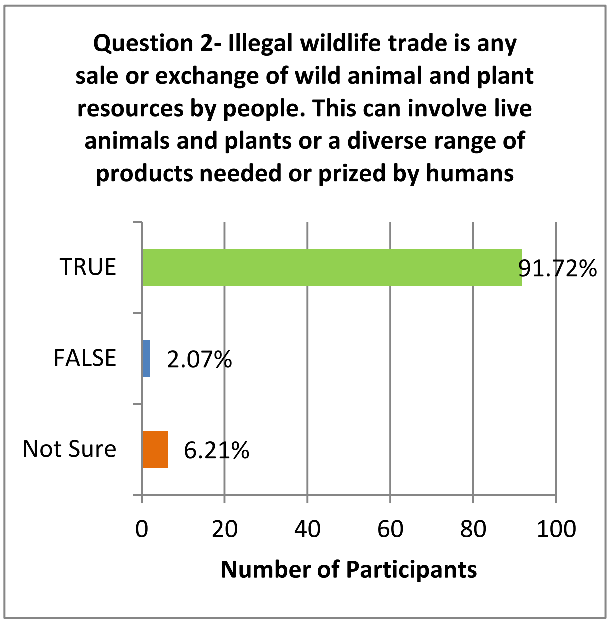
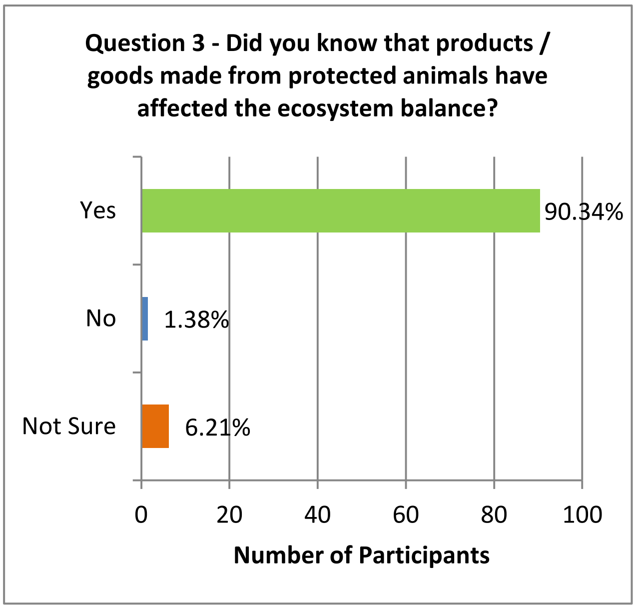
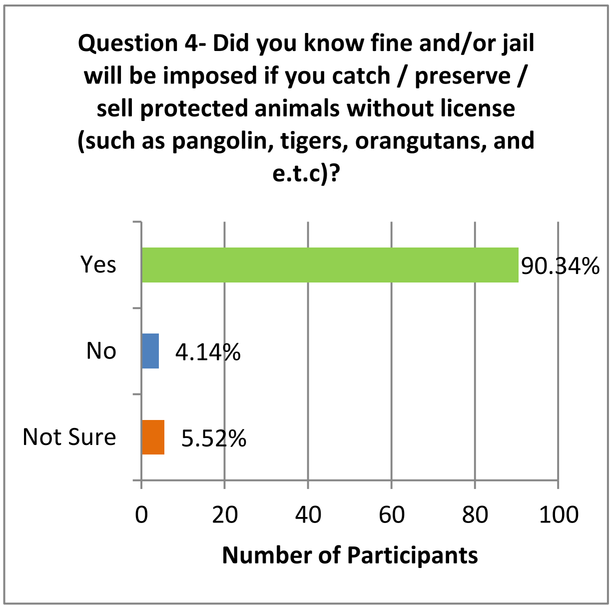


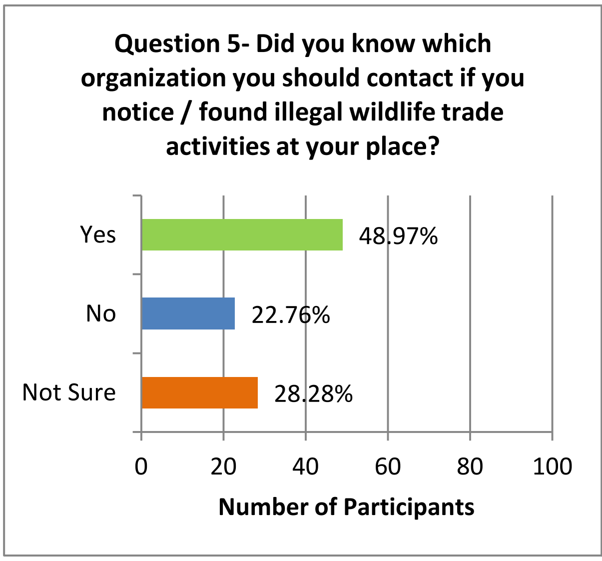
Figure 14 Occupation of participants

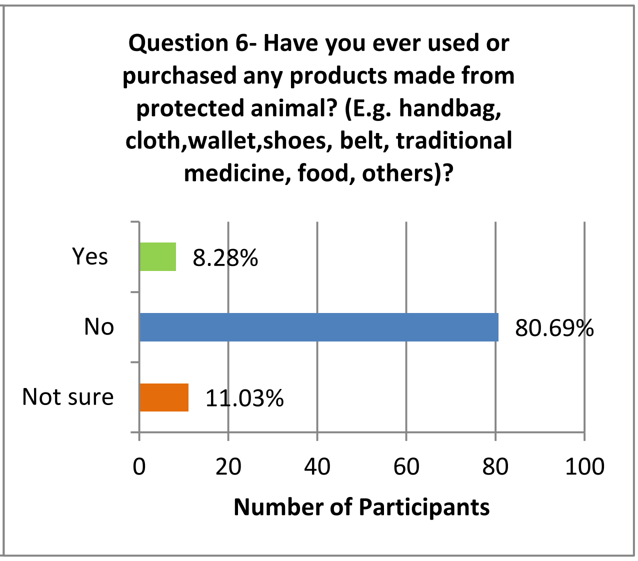












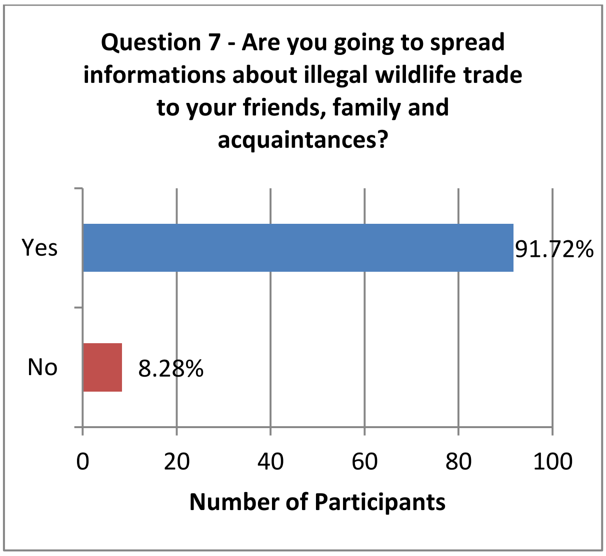


Figure 15 Survey questions used for the World Environment Day

Question 5 is about which organization should be contacted if illegal wildlife trade activities were found at our place. 71 participants knew which organization should be informed while 33 participants do not know, and 41 participants were not sure who should be contacted. Question 6 was on the purchasing of any products made from protected animal. Most of the participants (117 people; 80.69%) are not using or purchasing the product from protected animals, 16 of them are not sure and the rest have used or purchased the product. Last but not least, question 7 is about dissemination of information on illegal wildlife trade to your friends, family and acquaintances. 133 participants (91.72%) agreed to convey information to their acquaintances while 12 participants (8.28%) chose “No”.

CONCLUSION

Managing the national biodiversity databases requires time and significant input especially with regards to taxonomy and nomenclature to ensure that the information is up to date. Access to regular updates and up-to-date information are required to increase public awareness on the importance of biodiversity and thus contribute to the implementation of national strategies and action plans.

In the future, we will look into the development on Citizen Science, Taxon Data Information Sheets (TDIS), Specimen Digital Images, Invasive Alien Species, Communication, Education & Public Awareness (CEPA), National Conservation Trust Fund website and expert diaries. Furthermore, the data provided in the system will be able to help the public, various agencies, stakeholders, and policy makers for better implementation of the national biodiversity strategies and action plans. We hope that we can collaborate with more agencies to achieve better understanding about Malaysia biodiversity – our invaluable treasure.

ACKNOWLEDGEMENT

We thank the Ministry of Energy and Natural Resources for funding this project and to those who directly and indirectly help us achieving our mission and vision.

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ECONOMIC & SOCIAL FORESTRY

HUMAN DIMENSIONS OF FIREFLY WATCHING EXPERIENCE IN KAMPUNG KUANTAN, MALAYSIA

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Fireflies and its ability to produce light has inspired wonder and benefited mankind through various scientific research. The beauty of fireflies in producing light has become a very popular firefly watching activity worldwide. As a unique insect, firefly has been a tourism icon in Kuala Selangor and benefits the local community. This research focused on the human dimensions of the firefly conservation in Kampung Kuantan Firefly Park (KKFP). The emphasize was on the level of perceptions and willingness to pay (WTP) between the local community and visitors towards firefly conservation. The face-to-face interview was conducted in September 2019, involving 330 visitors and 400 local communities. Results of the mean indicated that local community (M= 4.42) and visitors (M=4.31) had a positive perception to conserve fireflies as well as its benefits in the tourism sector. Visitors have agreed to protect and sustain fireflies to ensure their survival while enjoying the beauty of nature. Results on willingness to pay (WTP) for both respondent groups were RM12.80, where visitors were willing to pay more (RM12.93) compared to the local community (RM12.43) for the conservation of firefly and its' habitat in Kuala Selangor. This importance result of human dimensions towards the firefly watching experience can assist in designing and improving a more efficient strategy to conserve the firefly population for the future.

Keywords: Local communities, visitors, willingness to pay, perception, firefly conservation

INTRODUCTION

The wildlife tourism industry including firefly is becoming an increasingly important component and also become ecotourism icons including Malaysia. However, in recent years, the distribution and abundance of fireflies' populations were reported being declining across the world. Early indications suggest the firefly populations have shrunk in many places and disappeared from others as habitat loss, light pollution, and pesticides used were listed as the most serious threats (Lewis et al. 2020). To date, research on firefly conservation site is limited to genetic research (Cheng et al. 2017), distribution of fireflies (Jusoh et al. 2010) including species richness and abundance of fireflies (Foo & Mahadimenakbar 2015). Limited research has been done on the estimation of willingness to pay (WTP) and influencing factors on the conservation of firefly and its habitat.

The conservation of fireflies is an essential sign of human appreciation for the value of fireflies and its habitat. Conservation value serves to create awareness on the need for decisions to optimize proper ecosystem resource management (Amiri et al. 2015). The management of the firefly habitat requires strong support not only from tourists to ensure the conservation of the fireflies but also depends on the abundance and sustainability of firefly tourism. Therefore, the participation of the locals should not be overlooked as they are the initial proponents of tourism activities surrounding the firefly habitat and are also dependent on the firefly habitat as a source of income. Undoubtedly, if to halt and reverse the ongoing extinction of fireflies, it is crucial to investigate the public perception, such as the awareness of local communities and tourists, including the willingness to pay (WTP) that will lead towards firefly conservation. The perception of conservation is important in improving government policy on the environment as well as striving for the welfare of the people and the political system (Durand & Lazos 2008). The overall objectives of the research project were to determine the awareness, perception and attitude of the local communities and visitors and to identify factors influencing the willingness to pay for firefly conservation. This is a critical issue since knowledge on the factors determining WTP can be used to design a proper development of an effective strategy to maintain the sustainability of the firefly population.

In estimating the economic valuation of non-use value (natural resources), the contingent valuation is practicable and there is a federal agency use this method to estimate the degree of destruction or harm of the ecosystem. It is conceptualized to the question as of how much people are willing to pay directly for the conservation of natural resources at present or otherwise (Amiri et al. 2015). Nevertheless, the perception of society influences their actions whether they support the conservation of firefly or otherwise. The economic value of non-market goods or services can be estimated using Contingent Valuation Method, CVM (Mitchell & Carson 1989) and it contains Willingness to pay (WTP) concept, to identify the value of public affords to pay. WTP has often applied to non-use economic values such as the conservation of species and the maximum value that individuals are willing to pay for enjoying the natural beauty and improving the environmental quality (Reynisdottir et al. 2008). Kuala Selangor District Council (KSDC) states that the entrance fee is MYR50 per boat (maximum four persons), which the value has been fixed since 1970 and determined without proper measurement. This review is an input for KSDC to re-determine and re-evaluates the fees for financial assistance and maintenance for the conservation of firefly habitat. It also shows that conservation is an important effort towards local development, especially in socio-economic, cultural, and ecological aspects.

MATERIALS AND METHODS

Methods employed included participant observation and semi-structured interviews with respondents involving local communities and visitors (domestic and non-Malaysian). The primary data were collected using a questionnaire from the survey via face-to-face interviews with visitors. Stratified sampling was used in the sample selection and the questionnaire form had been prior tested for reliability. Stratified sampling is the division of population groups into small groups that share characteristics (Sharma 2017). The questionnaire was divided into four main sections: (A) the socio-demographic characteristics, (B) awareness, (C) perception, and attitude of firefly conservation, based on a 5-point Likert-type scale for assessment where 1 represents “strongly disagree," and 5 was "strongly agree". Section D pertains to WTP for firefly conservation. However, this article only focuses on Section (C), for the perception and WTP for firefly conservation. The questionnaire was designed in bilingual language (English and Malay) to facilitate respondents to understand the questions especially international visitors.

Sampling and Data Collection

The research conducted two levels of the interview, specifically at the visitor and community level. The total number of visitors to KKFP in 2018 is 57,368 (Kuala Selangor District Council 2019). Based on the total population, a total of 330 visitors were selected for a face-to-face interview. For the local community, a face-to-face survey was conducted in the six main villages namely Kampung Tok Empat Majid, Kampung Tanjung Siam Baharu, Kampung Kuantan, Kampung Sepakat and Kampung Asahan. Of the 751 respondents involved, only 730(330 visitors and 400 local communities) were valid for the analysis. The questionnaire was designed based on the previous research and adapted from Abd Rahman & Asmawi (2016), Roy (2016), Khan & Ali (2009), and Kuvan & Akan (2005). A pilot study was conducted as a pilot test and measured the reliability of the instrument involving 30 respondents.

In a contingent valuation study, five formats were used in the application of contingent valuation: open-ended WTP, iterative bidding, Dichotomous Choice (DC), contingent ranking and payment ladder (Garrod & Willis 1999). The questionnaire was designed to get the maximum amount of WTP for conservation fee and included hypotheticals market. In Dichotomous Double Bounded Choice (DBDC), the question provided two types of answers that are 'Yes' or 'No', where the respondent chooses 'Yes', then the higher bid amount will be offered and if the 'No' is otherwise. The starting value of the bid will be set as the specific value that the respondent is willing to pay for the conservation value. This study applied DBDC because it is more effective to elicit WTP than Single Bounded (Hanemann et al. 1991). Respondents were also asked about the maximum amount they would pay for the proposed service. There are questions that indicate the reason whether the respondent is willing or not to pay. The five bid values were set: MYR 1, MYR 3, MYR 5, MYR 7 and MYR 10. The respondents have been informed that the value set was for a given situation and no actual fees or payments needed.

RESULTS AND DISCUSSION

Socio-Demographic Profiles of Respondents

There were 730 respondents; 54.8% of the respondents were the local community, and the remaining 45.2% were the visitors. The local community respondents were 67.3% male, and 32.8% were female. More than half of the respondents, 63.8% of the local community, and 65% of the visitors were married. Most of the respondents' age was ranged from 21 to 40 years old. In terms of the education level, 53.8% of the local community had completed their secondary school education, and 61.8% of the visitors hold a diploma/degree. In terms of career, the majority of both respondents worked as private staff, 29.8% from the local community, and 45.8% among the visitors. In terms of income, the majority of the local community (38%) had income ranging from RM1001 to RM2000 and, the visitors (19.1%) had an income of more than RM5000.

Perceptions of Firefly Conservation

The level of perceptions showed that most communities agreed that firefly can be the main ecotourism attraction, the mean of community is 4.66 and the visitor is 4.34 (Table 1). This is because firefly is a natural resource that has the benefit of generating income among communities. According to Kirton et al. (2006), KKFP in Kuala Selangor is important for contributing to the ecotourism sectors and domestic tourism in Malaysia. The ecotourism segment provided opportunities for local society to conserve nature and enhance their socio-economic growth. As the number of visitors to KKFP increased by 59,110 in 2018 (KSDC 2019) compared to only 24,000 in 1995, this indicated that KKFP is well known locally and internationally.

Table 1 Perceptions of means score of community and visitor

	Statement	**Mean**	
		Local Community	**Visitor**
a.	I believe the mangrove forest will protect a lot of plants and animals.	4.31	4.27
b.	Protecting mangrove forest in Kuala Selangor can conserve fireflies at the same time.	4.34	4.41
c.	I believe conservation of firefly can increase Malaysia's heritage value.	4.38	4.30
d.	In my opinion, firefly can be a public attraction.	4.57	4.29
e.	In my opinion, firefly can be the main ecotourism attraction.	4.66	4.34
f.	In my opinion, firefly conservation can benefit the local community by generating income.	4.43	4.28
g.	To me, the visitor's education level is important in their perception towards the importance of firefly conservation.	4.08	4.22
h.	The cooperation between visitors, locals and certain parties will ensure the conservation of firefly in future.	4.51	4.40
i.	To me, the attraction of firefly contributes to Malaysia's economy.	4.52	4.25
	Overall mean	4.42	4.31

Analysis of Mann-Whitney value showed a significant difference between the visitor and local community perceptions of firefly conservation (Table 2). The perception of the local community was more concentrated on the benefits of the firefly population and the advantaged of ecotourism and the income generation. Visitor perceptions focused more on firefly habitat protection in ensuring their survival to enjoy the beauty of nature.

Table 2 Mann-Whitney value of perception on firefly conservation

Category	Descriptive mean	Mann-Whitney value	p-value
Local Community	4.42	59327	0.042
Visitor	4.31		

Note: Significant level at 5%

Willingness to Pay

The logit regression analysis used to determine the WTP model and focused on the visitors. It also to identify the significant variables by showing factor that determines visitors' WTP for the conservation of fireflies and habitats. Based on Table 3, the WTP value of the total respondents was RM12.80. Specifically, for the local community, the WTP was valued at RM12.43 and for the visitors; the WTP was valued at RM12.93. Although the local community WTP was valued lower than the visitor, the difference among the price was minimal, at only RM0.50. The WTP among the visitor is higher, as they have a higher income range than the local community. Statistically, their income range is 36.7%, or in the range of more than RM3000 per month. Therefore, it is acceptable that visitors had a higher WTP for firefly conservation. Also, the visitor felt that their experience is worth the money they spent (Mohd Aswad et al. 2011). Visitors preferred the place to be protected, as they wished a beautiful view for the upcoming tour, and they agreed that the money they paid should be used to preserve nature (Kamri 2013). The findings also showed that Malaysian visitors were willing to pay RM14.16 for firefly conservation, compared to international visitors, who are willing to pay RM11.18. The result showed that Malaysian visitors valued more for fireflies conservation than international visitors. Even though the income among the international visitors is higher, some choose to pay lower bids because they were dissatisfied with various issues, including lack of facilities, services, and others (Mohd Rusli et al. 2009). Visitors stated that they were unable to witness the beauty of the synchronous light of the firefly as it was being promoted, so they were a little disappointed that it did not meet their expectations. In conclusion, with the arrivals of KKFP visitors in 2018 was 57, 368 and the total population of the local community in 2018 was 6,213 (KSDC 2019), the estimated total economic value is RM741, 768.24 (visitors) and RM77, 227.59 (local community).

Table 3 The estimation of the mean value of the willingness to pay

WTP	Coef.	Std. Err.	Z	p > Z	95% Conf. Interval	
Overall respondent	12.80	-0.590	21.70	0.000	11.642	13.954
Local community	12.43	0.690	18.04	0.000	11.079	13.780
Visitors:	12.93	1.086	11.91	0.000	10.797	15.053
Domestic Visitor	14.16	1.124	12.59	0.000	11.955	16.361
International visitor	11.18	2.566	4.36	0.000	6.147	16.205

CONCLUSION

This study was designed to provide useful information in describing human dimensions involving the visitors and local communities in willingness to pay and their perception on the conservation of fireflies. It was the first attempt to examine the WTP of tourists and local communities in KKFP. Stakeholders including the local communities and visitors' perceptions are important to maintain the conservation of the natural environment, preservation, and nurture the fireflies' ecosystem. These important findings would assist the policymakers in designing stronger conservation policies and activities that will improve firefly conservation efforts. Protecting, preserving, and conserving should be the responsibility of everyone to ensure the sustainability of natural resources in the future.

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ECONOMIC VALUATION OF PERMANENT RESERVED FOREST (PRF) SERVICES AS FLOOD CONTROL AND WATER CATCHMENT FOR THE STATE OF KELANTAN

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More than half of the land area in the country remains covered by forests despite rapid development, and the government is committed to continue preserving the forest especially Permanent Reserved Forest (PRF). Forests which largely were PRF in Malaysia contributed about 55.3 % of the land area in the country. Forests play an important role especially in watershed benefits and also flood control. Forests act as sponges that absorb heavy rainfall and gradually release water throughout the year to the river, which can reduce the effects of floods and maintain river flows during the dry season. The reduction of forest cover areas could lead to an increase in annual runoff rates, hence promoting flood, especially during monsoon season. In order to manage as well as conserve the ecosystems of reserved forests, the economic analysis of PRF's ecosystem services must be conducted and documented. Therefore, in 2019 a study case was conducted to value the economic benefits of PRF's services such as flood control and water catchments areas specifically at Kelantan. The study found every month Kelantan's water catchments (at selected catchments) were able to produce raw water of at least 2100-9500 m^3/ha/month and can increase up to 3900-25,000 m^3/ha/month during monsoon season. Based on a survey of 1,043 households at Kelantan, it is estimated the economic value of PRF's services such as flood control and water catchment areas amounted to RM48 million annually. From the public's interest to contribute to the PRF's services at Kelantan, it indicates that more concerted effort is needed by both the federal and state governments to conserve and preserve the forest ecosystem in Malaysia.

Keywords: Forest ecosystem services, economic valuation, watershed

INTRODUCTION

Forest management in Malaysia in recent years is not only focusing on timber production activities to supply the needs of the timber industry, but also on water resource management. Forest areas are recognised as an important source of water supply for domestic, agricultural, industrial and recreational purposes. However, forest areas are facing threats for land use conversion due to development projects. As a result, the water catchment areas are exposed to the same threat of danger. Based on a study by Benavides & Veenstra (2005), deforestation activities lead to issues and impact the river water quality due to increased concentrations of sediment, nitrogen and phosphorus.

Recognising this threat, the Forestry Department of Peninsular Malaysia (FDPM) has taken proactive steps to gazette Permanent Reserved Forest (PRF) areas that supply water to river catchment as Water Catchment Forest. Until 2020, an area of 1,046,117.30 hectares, which is 21.74% of the 4.81 million hectares of PFR areas in Peninsular Malaysia has been identified as Water Catchment Forest. Meanwhile, a total of 905,772.13 hectares, about 86.58% of the pre-determined potential areas for Water Catchment Forest, has been gazetted as Water Catchment Forest (FDPM 2020). In addition, the formulation of the National Water Resources Policy (NWRP) 2012 was held with the awareness to conserve water resources to ensure the supply of water for all consumer sectors, namely humans and the environment so that their needs are met in terms of quantity and quality. Among the main focus of NWRP is the guarantee of water resources supply and the sustainability of water resources.

The cleanest water supply comes from rain filtered through forests and ends in rivers. Forests help to prevent pollution from entering the rivers, lakes and groundwater in several ways. This process is called "natural water purification". This is the most valuable ecosystem aspect of ecosystem services, where water that passes through a good and less polluted ecosystem will have less water treatment costs. Water Catchment Forest has been one of the major contributors to the clean water supply in Malaysia. One of the benefits provided by Water Catchment Forest in terms of water quality is reducing the cost for water treatment. The concept behind this service is very simple, where water that flows or is being absorbed through forests or other natural ecosystems tends to be less polluted than water discharged by agriculture, urban or industrial landscapes. Therefore, the polluted water needs more treatment before it is safe to be supplied.

Recognising this important benefit, Water Catchment Forest, which is typically located in high altitude areas, should not be involved in commercial harvesting activities. To prevent such threat, an economic assessment of forest ecosystem services for water resources, represented by forest functions, is needed to determine the economic value of gazetted Water Catchment Forest to ensure continuous conservation efforts of the forests.

Therefore, the purpose of this study is to estimate the economic value of environmental ecosystem services of Kelantan's Permanent Reserved Forest (PRF) as Flood Control and Water Catchment. The specific objectives are:-

i. To determine the volume of water that can be obtained from Kelantan's PRF areas that serve as water catchment forests;
ii. To estimate the value of direct use from Kelantan's PRF for the purpose of clean water supply for domestic use; and
iii. Estimating the value of the economic benefits of preserving Kelantan's PRF as a function of reducing the impact and risk of floods.

MATERIALS AND METHODS

Different approaches were used to obtain different types of research data. The approaches were in the form of field data collection, interviews, focus group discussions, and surveys. There are two types of data collected through this study, namely primary and secondary data. Primary data involves data collection on the field especially on water quantity, water samples for water quality, Rapid Rural Appraisal (RRA), and surveys on households/respondents. Secondary data involves collecting information from water treatment plants and printed materials such as annual reports, books, journals, and other related materials. Each method was briefly explained below.

Water Quality and Quantity

Generally, there are four main water catchments for Kelantan, namely Nenggiri, Pergau, Galas, and Lebir River. However, for this study three catchments (Lebir, Pergau, and Galas) were enough to represent the Kelantan's water catchment. The hydrological parameter involved was the volume of river discharge that flowed out of PRF. Apart from that, the physic-chemical water quality of river water was also observed. This study includes the following activities:

- Identify the location of water catchment outlets available through GIS image mapping.
- Check the outlets in the field and then measure the profile and velocity of the river current.
- Draw the boundary of the water catchment area through the outlets where the river flows using GIS applications.
- Calculate the volume of river discharge produced for each hectare of the water catchment area that has been determined from PRF areas. The water volume value that has been identified will be used in the conservation funding application that has been selected.

Water Purification

The range of potential benefits of watershed service is much wider, including reduced treatment cost of water supplies, reduced cost of hydropower reservoirs, reduced risk of flooding and reduced cost of dredging. However, this study only focuses on reducing the treatment cost of the water supplies model. The model aims to calculate the annual payment that a water treatment plant should pay for the water purification service provided by virgin/logged forests. The assumption is that the payment is made to ensure that forests are not converted to agriculture (rubber, oil palm etc.) or other non-forest land uses. The main approaches in this model are:

- Obtain information of water treatment plants (coordinates, water production data and operation cost data).
- Locate the coordinate of the water intake and delineated water treatment plant catchments area.
- Overlay the information with National Forest Inventory and Land Use Survey data.
- Conduct econometric analysis-cost function approach.

Economic Value of Forest Service as Flood Control and Water Catchment Areas

The selection of methods to measure economic value depends on the goods and services, and the objective of the study. For this study, the valuation technique of non-market goods and services, namely the Contingent Valuation Method (CVM) was applied. The Contingent Valuation Method (CVM) is the most commonly used method to quantify the economic value and benefits of environmental goods and services, in which respondents are directly asked on how much they are willing to pay for conserving the environmental goods and services. These methods are closely related to the individual's behaviour in a hypothetical setting. The value can be obtained through a questionnaire which consists of the amount of unit goods at a given price. The questionnaire must be well-designed to ensure the response and accuracy of respondents during the interview. Well-structured and implemented CVM studies can produce reliable estimated value (Bann 1994).

The approach of CVM was the dichotomous choice – double bounded format. The format allows the respondents to choose the amount of WTP. There were 5 different bids given to different respondents randomly. Through this format, the response 'yes' or 'no' was needed for the WTP questions. There are 6 different bids (RM10, RM30, RM50, RM100, RM150 and RM200) given to different respondents randomly. The exploration of whether a person is willing to pay for the conservation of Kelantan's PRF for flood control was done using the Logistic model and Ordinary Least Squares (OLS) models. These models were chosen because of their ability to deal with a dichotomous dependent variable and a well-established theoretical background. The respondents for this study were randomly sampled by the Department of Statistics Malaysia. A total of 1,043 respondents from Kelantan were interviewed in December 2019.

RESULTS AND DISCUSSION

Water Quality and Quantity

Forests play an important role in ensuring the balance of the hydrological cycle within the forested catchment area. It affects the surface flow that reaches into the riverine system and ensures continuous flow (regulator). The forest ecosystem acts like a sponge that absorbs and stores water below ground level. It also maintains clean water quality by acting as a rain filter and slows down the running process towards the river.

From the study, the results showed water quality index in Galas and Lebir catchments ranged from class I to class III. The index varied depending on the season, for example during stream flow the index can be up to class III. However, for Pergau the water index maintains in class I for any season. This is due to the PRF land use, in which Galas and Lebir consists of plantation zone, while in Pergau is a protected area. These catchments are estimated to be able to produce at least 2,100-9,500 m^3/ha/month (August) raw water resources and can increase up to 3,900-25,000 m^3/ha/month in November. Table 1 shows a summary of the results.

Table 1 Water production discharged from the water catchment area

Water catchment	Location	Area (ha)	Min Quantity (m^3/ha)	Max Quantity (m^3/ha)
Pergau	Sg. Renyok	1,413	4,284	12,175
	Sg. Renyok WI	357	4,374	11,404
	Sg. Suda WI	2,638	3,856	6,873
	Sg. Suda I	225	2,476	5,416
	Sg. Pergau	6,650	4,631	6,931
Galas	Hulu Sg Galas	192	5,603	15,429
	Sg. Malin	406	2,126	3,899
	Sg. Tuang	2,063	3,198	9,510
Lebir	Sg. Lebir kecil	3,014	2,095	25,344
	Sg. Terong	8,057	3,729	4,426

Water Purification

Forests are natural water purifying agents that are very effective in supplying clean water resources to consumers, especially for domestic use. These water purification services have been extensively studied and are among the important ecosystem services for safety, guarantee of resource availability, health, facilities for clean domestic water. The results of the analysis show that the marginal value for PRF area in Lebir, Galas and Pergau Basins is RM0.28/m^3, RM0.30/m^3 and RM0.16/m^3 respectively (Table 2). The marginal value is influenced by the total area of forest land use type, such as the virgin forest in the basin. The high percentage of the virgin forest gives lower marginal implications. The type of land use of PRF gazetted such as the plantation zone area in the Galas and Lebir Basin also has implications of increasing marginal value. According to a study conducted in the states of Perak and Pahang (Vincent et al. 2015), the marginal value for the State of Kelantan is higher.

Table 2 Summary results for the economic value of water purification services

Watershed	Total annual production of clean water (m3)	Marginal Value of PRF (RM/year)	RM/m^3
Lebir	14,796,658	4,135,420	0.28
Galas	13,729,758	4,085,977	0.30
Pergau	6,196,872	972,075	0.16
Total	**34,723,288**	**9,193,472**	**0.25**

To ensure lower water treatment costs and reduce consumer burden on higher charges of obtaining clean water from water treatment, water catchment forest areas for water supply to water treatment plants need to be protected and maintained. It is hoped that Kelantan Forestry Department will limit the conversion of forest type zones, such as the plantation zone in the upstream area which is the main source of water catchment. The structure and planning of forest land use should be emphasized because it will impact not only the water supply but also other important services such as reducing the risk of floods and others.

Economic Value of Forest Service as Flood Control and Water Catchment Areas

There are four models involved in estimating the mean and median value of Willingness-to-pay (WTP), namely through logistic, biprobit, OLS and tobit analysis. The calculated mean and median values are listed according to models estimated using different approaches in Table 3**.** From the overall results, the mean WTP was found to be slightly higher than the median WTP. Referring to estimates obtained from positive WTP responses, the biprobit model has slightly higher estimates than other models, with the mean WTP was RM139.43.

Table 3 Summary results for the economic value of PRF services as flood control and water catchment

Models		Mean Willingness-to-pay (RM)	Median Willingness-to-pay (RM)
Logistic	Initial bid	131.66	130.38
Biprobit	Initial bid	139.43	130.64
	Follow-up bid	112.06	65.86
OLS		69.39	n.a.
Tobit		69.39	n.a.

To aggregate the WTP in determining the economic value of PRF services as flood control and water catchment, the individual WTP obtained from the analysis was multiplied by the number of Kelantan household population (2016 = 341,600). The yearly calculated economic value or benefits of preserving Kelantan's PRF based on the mean willingness to pay computed from respected models for the year 2019 are RM44.9 million (logistic), RM47.6 million (biprobit) and RM3.7 million (OLS). If there is a proposal to charge (example: in the form of tax) for Kelantan's PRF conservation fund, the maximum amount found in this study is RM139.43/year, which can be used by the authorities to determine the appropriate conservation/conservation fee.

CONCLUSION

This finding provides useful evidence to support and helps the formulation of policies that protect and manage Kelantan's PRF by quantifying the economic value of environmental ecosystem services of Kelantan's Permanent Reserved Forest (PRF) such as Flood Control and Water Catchment. It also serves as an important guideline to assist the management in decision-making in terms of welfare measures and conservation benefits especially considering the importance of natural resources to meet developmental needs and other economic activities.

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DESIGNING AND INSTITUTIONALISING AN ECOTOURISM PROGRAMME TO CREATE ECONOMIC INCENTIVES FOR FOREST CONSERVATION: AN INSPIRING STORY FROM LOCAL COMMUNITIES IN KAMPUNG JANDA BAIK, PAHANG

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Nature-based tourism in Malaysia has started to attract the attention of various stakeholders in terms of projects and investments. The Malaysian economy has greatly benefited from the increase in tourists from 17.55 million in 2011 to 26.1 million in 2019, with income generated reaching RM86.1 billion (approximately USD 21 billion) in 2019. The scenario was seen as an opportunity for locals living in the tourist destination to reap socio-economic gains while ensuring that forests and protected areas in the tourist area are conserved. The research aims to create financial incentives to strengthen the local community's involvement in biodiversity conservation through ecotourism at Ulu Tampik Waterfall (UTW), Lentang Forest Reserve, Bentong, Pahang. Rapid rural appraisal, survey, and field research were conducted to estimate the economic benefits of preserving the forest area based on public preferences. The research used the economic valuation of the nature tourism area, focusing on estimating the economic benefits of preserving the UTW area based on public preferences. It examined 149 respondents to estimate willingness to pay (WTP) for natural resource conservation using the contingent valuation method. Also, a few strategies were adopted to empower the local community including stakeholders' consultation workshops, technical visits and a study tour to one of Malaysia's best practices community-based ecotourism. Such programmes indirectly educate and empower their knowledge, experience, and support in natural resource conservation.

Keywords: Willingness to pay, community-based ecotourism, capacity building, social forestry, conservation

INTRODUCTION

Southeast Asia's forests play a central role in reducing poverty, combating the impacts of climate change, addressing food security, and contributing to the economic development of the region. Approximately 625 million people or more than 50% of the Association of Southeast Asian Nations (ASEAN) region's population rely directly or indirectly on forest resources for their livelihood and survival (FAO 2010). Forests, therefore, must be sustainably managed to continuously produce food, fuelwood, timber, and medicine or even tourism without sacrificing the ecosystem services provided by these forests to stimulate economic growth. According to the World Tourism Organization

(UNWTO), tourism is one of the important sectors that contribute to economic growth. However, Malaysia faced a critical phase since the COVID-19 outbreak as it becomes one of the threats to tourism industries which tourism sector in Malaysia lost about RM45 billion (10 million USD) due to the outbreak (Bernama 2020).

Currently, Malaysia focused on domestic tourism and natural attractions have been the best choice to visit especially for urban dwellers who need peace of mind. Malaysia has adopted ecotourism as an approach to forest conservation as well as a means of uplifting the socio-economic status of local communities. Ecotourism has tremendously contributed to forest conservation efforts and positive socio-economic implications by providing for the self-financing of protected areas through user fees and concessions. For instance, the project entitled "Conservation and consumption goods and nature-based recreation: A community-based ecotourism project in Malaysia" focused to reduce forest biodiversity loss for the benefit of local communities. Community-Based Tourism or Community-Based Ecotourism (CBT/CBET) is often regarded as a panacea by creating an alternative source of livelihood once protected areas are gazette around or close to local communities who used to be dependent on the forest resources. Numerous studies on CBET nexus have demonstrated the critical role of livelihood participation and active contribution as a pathway for poverty alleviation (e.g., Hamzah et al. 2012; Saufi et al. 2014). CBET is also widely used as an economic incentive to achieve specific conservation strategies, such as habitat or species protection, or even integration between conservation and development project (Sakata & Prideaux 2014). The development of CBT/CBET has contributed to the benefits of the socio-economic local community (Pichdara et al. 2018) and indirectly increased awareness among the locals about cultural and heritage preservation (Logar 2009). The communities also acknowledged positive economic and environmental outcomes (Sakata & Prideaux 2014), improved locals' well-being, and encouraged individuals to conserve forests and wildlife (Stem et al. 2003).

The research presented here explores the potential of ecotourism as a conservation tool for socio-economic improvement among local communities. The principle objective is to improve the socio-economic benefits of the local people by maximizing their financial return from ecotourism development, which in turn will lead to better involvement and commitment to the management of forest resources among local communities. The research also intends to increase the knowledge and raise awareness of the local communities on forest conservation through education and consultation workshops. This research indirectly aimed to strengthen conservation efforts through the use of economic and financial tools as a model for effective forest management.

MATERIALS AND METHODS

This research area involved the Ulu Tampik Waterfall (UTW), located in Janda Baik, Bentong, Pahang, Malaysia. UTW is located in compartment 51, Lentang Forest Reserve with a unique, tranquil ambience and exciting recreational area. In terms of topography, this environment is within the Titiwangsa Range and hilly areas with an altitude between 600 m and 800 m above sea level. The main physical component is the uniqueness of the waterfall and its clean and clear water. The UTW and its environment is a popular recreation area for residents of Janda Baik, visitors from other areas as well as foreigners. Previously, the area was within the Use Permit area, operated by a private agency namely Sitrac Corporation Berhad. The area is managed by Bentong District Forest Office and the land is a protected water catchment area. Data collection involved various techniques, namely rapid rural appraisal, survey research, field research, and capacity building to empower local community awareness, communication skills, and understanding.

Baseline research studies were conducted from March to December 2018 to estimate the economic benefits of preserving the UTW nature tourism area and its surroundings based on public preferences. The rapid rural appraisal technique was carried out to enable a quick assessment of the particular group of individuals, households, or communities living in the vicinity of the UTW. It provided a general overview of the existing conflicts and the perception of the community towards the conservation of Lentang Forest Reserve (LFR). This baseline research used an economic valuation to focus on assessing the value of the UTW nature tourism area and its surroundings. In the absence of price, the research adopted the hypothetical scenario using the Contingent Valuation Method (CVM) to estimate the value. This economic value is a benchmark for nature conservation awareness (De Groot et al. 2012) and this technique has been used to price non-market goods or services of ecosystems (Ajzen & Driver 1992). The measurement included a willingness to pay (WTP) for the conservation of nature tourism areas.

The public preferences or users (tourists) survey applied a CVM to estimate WTP which later will be used to determine appropriate conservation fees for the UTW. The research used conservation fees as a payment vehicle. The dichotomous double-bounded format with different bid prices (e.g., RM2, RM8, RM10, RM15, and RM20) has been used in the questionnaire and face-to-face interview. The WTP measures involved dichotomous format namely the Logistic model and open-ended known as the ordinary least squares (OLS) model. The socio-demographic information includes the background of the visitors such as their gender, age, educational level, marital status, profession, income, and origin. Data obtained from 149 respondents were used to analyse the factors influencing the demand for the recreation site at the UTW using descriptive analysis and followed by the Logistic and OLS models.

Research objectives for increasing knowledge and raising awareness among the local communities on forest conservation were obtained through a few series of meetings. This included various focus group discussion sessions with the head of villagers, local state authorities, and Pahang state Forestry Department. At the local community level, a few workshop series and stakeholder consultations have been organized. The local communities agreed and gave their consent to the establishment of Sahabat Alam Tampik Janda Baik (SATJB) on July 2018, previously known as Tampik Janda Baik Eco-Forest committee. This method was consistent with the approach of the Joint Forest Management (JFM) mechanism through the establishment of a special committee. The selection of the Committee Members was appointed during a special meeting and the membership was restricted to residents of Kg. Janda Baik only.

Lessons learned from previous CBT/CBET projects including low levels of education and lack of knowledge about tourism as the barriers to local community participation (Kim et al. 2014) motivated the project to conduct several workshops purposely to enhance practical training experience, capacity building, and communication skills on the ecotourism development. These methods indirectly will expand their knowledge of nature conservation throughout the two years project which required long-term commitment from local communities. Critical success indicators of community capacity building include local participation, knowledge, and skills of the local community, leadership, community structure, a sense of community, and external partnership (Razzaq et al. 2011), researchers continuously trained and empowered them to enhance positive perceptions and sense of belongings to their village.

The first stakeholder consultation workshop was organized at the village level, with the theme “Conservation of forests through sustainable eco-tourism”. The workshop resolutions agreed on the active participation of locals throughout the implementation of the project and the establishment of the special committee. The technical site visit and discussions with the Peninsular Forestry Department, The State Forestry Department, the private corporation, and local communities were organized in June 2018. The UTW area with 30 hectares (74 acres) was requested to be handed over to the local community through a use permit to be fully managed as a community-based ecotourism project site. The official application was made to Pahang State Forestry Department with assistance and technical advice from Forest Research Institute Malaysia (FRIM) in October 2018.

Local communities had opportunities to upgrade knowledge and capabilities with first-hand experience through the study tour and short course session at Miso Walai Homestay under the Koperasi Ekopelancongan (Ecotourism Cooperative) Kg. Batu Puteh, Kinabatangan or known as KOPEL, Sabah in October 2018. The next stakeholder consultation workshop on "Identification of ecotourism activities and potential packages" was organized from 21 to 22 November 2018. Selected local communities of Kg. Janda Baik were registered for the Local Nature Tourist Guide Course held from 13 to 29 November 2018. Throughout the course, candidates should be very disciplined and knowledgeable about ecotourism and the country as a whole and must also pass a MOTAC examination to obtain a license as a Green Badge Nature Tourist Guide. This badge symbolizes national qualification and provides recognized evidence of excellence in guiding skills. The course is accredited by the Malaysia Tourist Guide Associations, the government-approved standard-setting and registration guiding sector in Malaysia. The six selected individuals were also eligible to be registered for an official license of Nature Tourist Guide. This was a great achievement for the local communities of Kg. Janda Baik and the success story of the SATJB Committee.

The Environmental Interpretation Short Course organised in April 2019 with the attendance of 25 local communities involved in the full-time and part-time nature and tourist guides strengthened their understanding of ecological contexts and raise awareness about human behaviour in forest nature. This short course provided an understanding of nature interpretation as a tool for education, recreation, and conservation of the natural environment particularly the UTW nature area and its surroundings. Participants learned about methods, skills, and tools for practical nature interpretation. Then, to assess forest biodiversity and environmental conservation, locals participated in the assessment of flora and fauna along the UTW trail to identify and complete the inventories from 14 to 17 June 2019.

RESULTS AND DISCUSSION

The UTW area has resources for various recreational activities, ranging from active to passive activities. Visitors can enjoy the natural resources such as the interesting waterfalls, clear rivers, and plants of interesting forms, the wilderness with its scientific and scenic aspects as well as experience and feel the remoteness and clean environment by being close to nature. In measuring the WTP of the visitors, they were asked to indicate their willingness to pay for the conservation of the resources in the UTW area. The analysis shows that 87% of the respondents agreed, while 13% did not agree to contribute to the conservation of the UTW area. The respondents who were not willing to pay indicated that the government was responsible for the conservation and development of the area. The frequency analysis shows that the WTP for the conservation fee of the UTW ranges from RM1 to RM80, with a mean WTP of RM14.35. The mean WTP for foreign and domestic visitors are RM16.28 and RM14.04 respectively.

The main achievement of this project was the establishment of the Sahabat Alam Tampik Janda Baik (SATJB) committee on 8 July 2019 and officially registered under the Registrar of Societies (ROS) on 5 March 2019 (Reg. No. PPM- 013- 0615032019). This society has been officially legalised to generate income, profit sharing and received funds, training opportunities, technical assistance, and support from relevant authorities and agencies at national, or international levels. This indirectly allowed the association to be a qualified entity for financial assistance from any government agencies either local, national, or international donors. Four (4) workshops and short courses have been organized to enhance local community skills in ecotourism site management. Besides that, six (6) locals were successfully trained to obtain green batch licenses for nature guides. FRIM researchers also assisted in the development of promotional material, including website development and corporate video production. Since March 2019, the development of an interactive website as a promotional tool known as "Tampikwaterfall.com" has helped nature lovers to retrieve updates and the latest announcements about the waterfall and special committee.

To strengthen the function of the society, a meeting with Pahang Forestry Department was conducted and an official application was sent to the Pahang state government to apply for leasing 30 hectares of the UTW area. Through the proposal, the leasing area will be managed by the local community through the SATJB committee for recreation and ecotourism purposes, at the same time ensuring conservation of the area, as well as obtaining a continuous benefit for the local community surrounding the area. The period of the application process from October 2018 to February 2020 finally resulted in a successful approval by the state government (State of Pahang, Malaysia) on 16 April 2020. Along with the approval from the state authority through State Executive Council Meeting in leasing the UTW for locals' community management, this set an example for effective forest management through "joint management' practice and as a community-based ecotourism project site.

The outcome of the project involved varieties of output such as a technical report on the assessment of conservation value of forest resources in the UTW and its surrounding area, different itineraries for community-based ecotourism, a collective plan for the UTW ecotourism development and management with inputs from local communities. The official launch of the SATJB and the Kg. Janda Baik community-based ecotourism on 20 October 2020 was the most recent achievement for local communities, in particular, the Special Committee. This news stated that SATJB is a pioneer for community-based ecotourism in Peninsular Malaysia. The event was launched and officiated by the YB Dato' Sri Hj. Mohd Sharkar bin Hj Shamsudin, Chairman of Pahang State Tourism, Environment and Plantation Committee (Amirnordin 2020). As for three months of operation (July–September 2020), the committee gained income of more than RM30,000 and transferred the RM9,000 to the Pahang Forestry State Department for the permit payment. Leadership, motivation and interest, technical knowledge and skills, strong local organisations, rights, and equitable benefit-sharing mechanism have been key characteristics to encourage a spirit of engagement among participating households. For long-term benefits sharing, there is a need to develop sufficient momentum and future planning for sustainable achievements, active, and continuous progress.

CONCLUSION

This study was the first to present an achievement on the development of a community-based ecotourism (CBET) model for Peninsular Malaysia. The two-year journey has been successful in empowering local communities to participate in assisting the government and relevant authorities to formulate conservation strategies and actions. The establishment of community-based management practices has enabled to mitigation of human-environment and natural resource conflicts. FRIM as the technical advisor to CBET is continually educating and empowering the local communities specifically in Kg. Janda Baik to put an effort for greater support and engagement in natural resource conservation. To ensure the sustainability of community-based eco-tourism, dynamic leadership and organization should be enhanced. The establishment of local and legal society, including partnerships with government agencies and tourism industry players with a strong commitment from the association (SATJB), is part of the model of the community-based ecotourism initiative in Peninsular Malaysia.

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POLLINATION SERVICES SUPPORT FOR AGRICULTURE PRODUCTIONS VALUES

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Pollination is one of the ecosystem services provided by tropical forests as addressed in The Millennium Ecosystem Assessment. Roughly, two-thirds of the world's agriculture species cultivation required pollination. Studies showed that 70% of tropical crops seem to have at least one variety for which production is improved by animal pollinators. Most common pollinators live naturally in the ecosystem known as wild pollinators. The objective of this study was to quantify the economic value of pollination services by wild pollinators of Gunung Tebu Forest Reserves, Besut, Terengganu. Agricultural data was obtained from the Department of Agriculture Terengganu. Data incorporated the list of farmers/villages, types of crops planted, annual area planted (ha), annual area harvested (ha), annual production (kg), and annual production value (RM). The economic value of pollination services was estimated by multiplying the production value of each crop with its pollinator dependence ratio. This paper considered four types of crops, namely durian, watermelon, melon, and rambutan. The results of the analysis on the economic value of natural pollinator services based on pollinator dependence ratio were RM6,588,630.91. These accounted for 56% of the total production values for the region. It demonstrated that natural pollinators have important impacts and benefits to agricultural sectors through pollination services provided by the nearby forest. Crop production could be further increased with improved pollination services and would contribute significantly to world food security.

Keywords: Pollination services, economic value, wild pollinator

INTRODUCTION

Millennium Ecosystem Assessment (2003) and The Economics of Ecosystem Services and Biodiversity (TEEB) has outlined pollination services as one of the regulating services (MEA 2005; TEEB 2010). Globally, one-third of the total human food supply depends on pollination. The production of agricultural crops is increasing by 50% through pollination (Klien et al. 2007). With improved pollination, crop yields could be further increased by about 25 per cent. By ensuring higher yields and successful agricultural production, pollination would contribute significantly to world food security (FAO 2018).

Pollination services for tropical crops have been compiled by Raubik (1995) with a list of potential breeding systems and pollinating taxa. Throughout the list, about 70% of tropical crops seem to have at least one variety for which production is improved by animal pollinators. Most common pollinators live naturally in the ecosystem known as wild pollinators. It refers to a species of animals and insects native to a particular area, aiding in the pollination of both agricultural and wild plants. The distance between nesting place and food is also important as flight involves a cost for insects. It is also thought that the amount of nectar and pollen and the length of the period when food is available are important in maintaining populations of wild pollinators.

Relationships between natural areas such as forests and pollination are closely linked. Rickett et al. (2008) illustrated by proving that the number of crops visited by wild pollinators is lower in crop areas farther from natural habitat. Only about 0.5 per cent of wild pollinators visit tropical crops within 5000 meters of their natural habitat. This showed that the farther the crops are from natural habitat, the less potential the pollinators will visit.

Two methods have been used to assess the monetary value of pollinators (Gallei et al. 2009). The first method is simply assessing the total value of insect-pollinated crops. This approach has been used at a national scale in the USA and global scale (Constanza et al. 1997; Pimentel at al. 1997; Martin 1975). However, the production of most crops only partially reduces in the absence of pollinators; a more refined approach has been developed based on the previous approach. It takes into account the real impact of pollinators on crop production, called the dependence ratio. The dependence ratio enables the calculation of the production loss in case of the complete disappearance of pollinators, and the economic value of pollination services would assimilate with the loss of crop value.

The dependence of tropical crops on pollen animals has been extensively studied (Paull & Duarte 2011; Klien et al. 2007; Raiubik et al. 1997; Earl of Cranbrook 1988). Klien et al. (2007) published the dependency ratio which the value of this ratio determines the average values of pollinator reliance on the crop. There are several stages of dependency ratio:

i) 95% refers to the average value of reduction of pollen-driven yields is between 100% and 90% in experiments comparing commercial produce with and without animal pollinators. Pollination is reported as “Essential”.
ii) 65% refers to a reduction of pollen driven revenue is between 40% and less than 90%. Pollination is reported as "Great".
iii) 25% refers to a reduction of pollen driven revenue is between 10% and less than 40%. Pollination is reported as "Modest".
iv) 5% refers to a reduction of pollen driven revenue is between> 0% and less than 10%. Pollination is reported as "Little".
v) There are also some plants that are not dependent on animal pollination and are also known as ‘Parthenocarpic’. However, the list of crops does not cover many crops found in the tropics.

This study aims to quantify the economic value of pollination services by wild pollinators in Malaysia, specifically in Gunung Tebu Forest Reserves (FR), Besut, Terengganu. The economic value estimates addressed the contribution of pollination services on the production of crops, thus securing some of the food supply in the region.

MATERIALS AND METHODS

Study Area

Malaysia is abundant in wild pollinators such as bees, stingless bees, and bats. Several agricultural crops including starfruits, guava, citrus, mango, watermelon, durian, and coconut used pollination. Gunung Tebu, Besut, Terengganu was chosen as the study area due to their rich forest reserves. The area is located at the eastern of Malaysia covered with a total of 25,316 ha, about 24 km from Jertih town and 118 km from the capital city Kuala Terengganu. The reserves are rich in flora and fauna and also have several recreational attractions such as Lata Belantan Eco-Park and Gunung Tebu peak of 1,039 m in height.

Data Analysis

Data requirement in this study involved the agricultural monthly production reports gathered from the Besut and Setiu District Agricultural Department. The agricultural information collected from November 2019 to October 2020 includes;

i) Crops area (ha)
ii) Types of crops planted
iii) Total monthly production (kg)
iv) Production value (RM)

Based on Rickett et al. (2007), the information collected was strictly limited to a 5 km radius of Gunung Tebu FR. The map shows the area that is within a 5 km radius from the boundary of Gunung Tebu FR and was used to inform the Field Officer (Figure 1). Data gathered from Besut and Setiu District Agricultural Department as in Table 1.

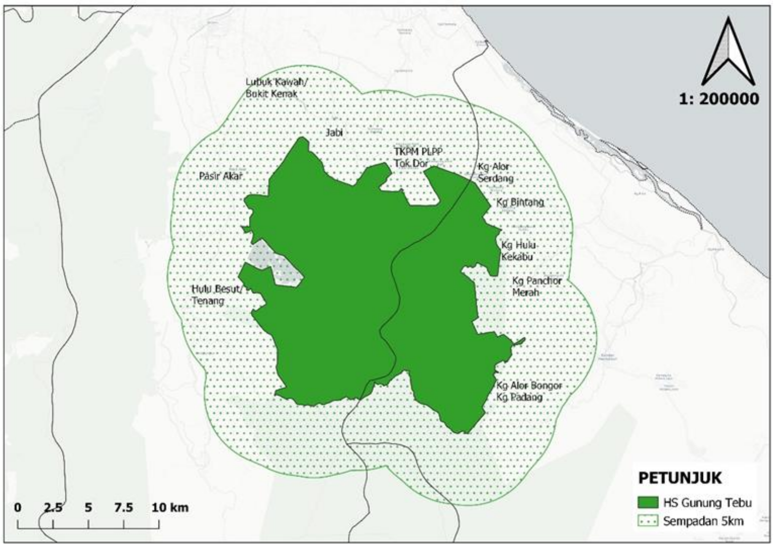

Figure 1 The map of the 5 km radius of Gunung Tebu FR

Table 1 Fruits/crops production data of Besut and Setiu

Crops	Production (kg)	Production value (RM)
Jackfruit	17,300.00	17,300.00
Dokong	42,577.00	43,848.40
Duku	90,080.00	120,864.00
Durian	1,947,873.00	9,492,017.90
Mangosteen	49,400.00	49,400.00
Banana	838,187.00	1,394,728.00
Rambutan	54,527.00	83,827.00
Snakefruit	22,320.00	49,104.00
Watermelon	398,590.00	360,610.45
Melon	72,700.00	75,840.00
Total	3,533,554.00	11,687,539.75

(Source: District Agriculture Department 2020)

Methodology Approaches

This study used the second approach to calculate the economic value of the pollination services. The total economic value is calculated using Gallei et al. 2009;

$$\mathrm{IPEV} = \sum_{i=1}^{I} \sum_{x=1}^{X} (P_{ix} \times Q_{ix} \times D_i)$$

Where Qix is the production quantity, (Di) is the ratio of crop i dependence to pollinator and (Pix) is the crop price i per production unit in area x. The values of some tropical crops' dependency ratios were listed by Klein et al. (2007) and also shown by Norowi et al. (1988) as in Table 2. Table 3 show the calculation of the economic value of selected fruits with the dependency ratio.

Table 2 Dependence ratio for local crops

Crops	**Pollinator Dependence Ratio**
Starfruits	0.65
Guava	0.65
Lime	0.05
Mango	0.65
Watermelon	0.95
Melon	0.95
Rambutan	0.05
Durian	0.65
Banana	*parthenocarpic*
Mangosteen	*parthenocarpic*
Duku	*Unknown*

Table 3 The economic value of pollination services by selected crops (calculation using Gallei et al. 2009)

Crops	Production (kg)	Production (kg)	Dependency ratio	Economic Value
Jackfruit	17,300.00	17,300.00		-
Dokong	42,577.00	43,848.40		-
Duku	90,080.00	120,864.00		-
Durian	1,947,873.00	9,492,017.90	0.65	6,169,811.64
Mangosteen	49,400.00	49,400.00		-
Banana	838,187.00	1,394,728.00		-
Rambutan	54,527.00	83,827.00	0.05	4,191.35
Snakefruit	22,320.00	49,104.00		-
Watermelon	398,590.00	360,610.45	0.95	342,579.93
Melon	72,700.00	75,840.00	0.95	72,048.00
Total	**3,533,554.00**	**11,687,539.75**		**6,588,630.91**

RESULTS AND DISCUSSION

There were ten types of crops grown around the Gunung Tebu FR, namely durian, banana, rambutan, watermelon, melon, duku, dokong, snakefruit, mangosteen and jackfruits. Durian is the largest producer of crops, followed by bananas and watermelon. The total yield production of crops is estimated to be 3,533,554 kg with a production value of RM11,687,539.80.

The estimation for economic value of pollination services is estimated only for durian, watermelon, melon and rambutan since their type of crops required pollination. Most of the pollinators are from natural habitats or wild pollinators. Other crops such as bananas and mangosteen have no dependency on pollinators (parthenocarpic). Meanwhile, pollinators were shown to be important for duku, dokong, jackfruits and snake fruits but the extent of the impacts is unknown. There have been few studies on pollination in these types of crops.

Based on the calculation using Gallei et al. (2009), the economic value of pollination for Gunung Tebu FR and Besut was RM6,588,630.91. The estimate is equal to 56% of the total production value (RM11,687,539.80) of the area. The actual value of this service will probably be higher than reported in the findings if other types of crops are considered. However, this value is only based on the result of HS Gunung Tebu. Crop yields could be increased further with improved pollination services, and successful agricultural production would contribute significantly to global food security.

CONCLUSION

The economic value of pollination services for four crops is estimated about 56% of the total crop's production value. It indicated potential pollination services for some crops in Malaysia. As the recommendation, the determination of pollination values should be based on an ecological and economic approach to avoid over and underestimation. For a better valuation on pollination services, the economic approach has to take into consideration in the analysis. These findings only give a brief scenario of the impact of pollinators on the production physically.

Hence, the support of pollination services for the production of crops is significant and valuable. It is not only for food resources of the community in the region but also contributed to another area since the production crops were exported. Natural habitats for pollinators such as forests must be protected to ensure the ecological sustainability of the service and the safety of food resources.

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CONTRIBUTION OF MANGROVE FOREST TO THE LIVELIHOOD OF LOCAL COMMUNITIES IN SUNGAI KUANTAN, PAHANG

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The conservation of mangrove forests means ensuring the livelihood of coastal communities that have benefited directly and indirectly from these natural habitats and ecosystems for generations. Ecosystem services provided by mangroves to humans come in many forms, especially as a source of food and raw materials used in daily life. In 2020, a case study was conducted to analyse the contribution of mangrove forests to local communities specifically at Sungai Kuantan, Pahang. A total of 384 households from nine villages were successfully interviewed. The study employed a socioeconomic survey on the households living in the adjacent of Sungai Kuantan mangrove forest, Pahang. The result of the study found that 70% of the coastal communities had visited and knew about the existence of mangrove forests near their villages. The study also found that 36% of them use the mangrove forest area in Sungai Kuantan either for the purpose of income generation, recreation or as part of their daily food source. On average, the monthly household income for the community living near the Sungai Kuantan mangrove forest is RM2,882 per month. Of that amount, 31.9% was contributed from Sungai Kuantan mangrove forest and the coastal areas nearby. The results of this study demonstrated that Sungai Kuantan mangrove forest is able to generate income hence, contributing to the livelihood of these coastal communities.

Keywords: Mangrove forest conservation, socio-economics and coastal communities

INTRODUCTION

Mangrove forests are among the most important types of forest in Malaysia, where Malaysia contributes 3.7% of world mangrove forest coverage (Wan Ahmad et al. 2018). Meanwhile, Abdul Shukor (2004) stated Malaysia's coastline is estimated to be 4,810 km distributed along with the West Coast Peninsular Malaysia, East Coast of Peninsular Malaysia, Sabah, and Sarawak. There are various types of ecosystems on the Malaysia coastline; one of the ecosystems is the mangrove forest ecosystem. Mangrove forests act as frontiers that protect the coastal land against the destruction of ocean waves.

Other than that, mangroves also provide habitat for various marine life forms, function as a natural filter that improves the quality of water and also plays important roles as a significant carbon sink in the coastal environment (Hamdan & Muhamad Afizzul 2020). Most importantly, the mangrove ecosystem is also a spawning and nursery ground for many marine shrimps and fishes. This made mangrove forests are among naturally fertile and productive areas as it serves as nesting and feeding ground for the biodiversity of life (Kamarulzaman et al. 2011).

Not only have extensive values, but mangrove resources also serve great importance to the socio-economy of the country, especially to the local community nearby mangrove forest ecosystem. The importance of these resources is derived from the direct goods harvested from the mangrove forests as well as from the amenities provided by the resource itself. The fisheries goods that are harvested from the mangrove ecosystem include mud crab, a variety of shrimp species, gastropods and also cockles. Together, they provide an important food source as well as able to generate income for a nearby community. Therefore, maintaining and conserving this mangrove ecosystem is very crucial not only for the mangroves but also for the well-being and livelihood of the local community.

Thus, in 2020 a study was conducted to analyse the contribution of mangrove forests to the livelihood of local communities specifically at Kuantan Mangrove Reserved Forest, Pahang.

MATERIALS AND METHODS

Study Area

Generally, Pahang is estimated to have 1.55 million hectares of forest reserved, of which 2,416 hectares are mangroves. Out of that, 339 hectares of mangrove forest coverage is at Kuantan, Pahang. This green little pocket of Kuantan town not only provides a variety of goods and services which contribute to the well-being and livelihood of the local community, but also serves as an ecotourism spot, especially for domestic visitors. However, this paper only focuses on the contribution of mangrove forests to the local community.

A total of nine (9) villages were selected to be sampled in this study, namely Kampung Anak Air, Kampung Belukar, Kampung Kempadang, Kampung Peramu, Kampung Permatang Badak, Kampung Sungai Isap, Kampung Tanah Putih, Kampung Tanjung Api dan Kampung Tanjung Lumpur. These villages were sampled together with the Kuantan Land District Office.

Research Approach

There are two main research approaches applied in this study: Rapid Rural Appraisal (RRA) and a household survey. RRA techniques are widely used globally; research by Ganesh (2010), Jarrett & Lucas (2003), Alayne (1997), Wenresti (1995), Melville (1993) also applied this approach in their study. This RRA technique is a tool that enables a quick assessment of the existing environment and the possible impacts of the resource utilization and the other environmental services to the local socio-economics livelihood (Liswanti et al. 2012). The techniques applied in RRA include group interviews; methods of cross-checking information from different sources; direct observation at the study site level and use of secondary data (Crawford 1997). This technique provides useful information to be implied in questionnaire design. In this study, RRA applied on the preliminary stage of the study to gather baseline information and understand the roles of mangroves and their contribution towards local community lives nearby the study area.

The household survey included a face-to-face interview, guided by structured questionnaires. The questionnaire was constructed into a few sections covering the household's income sources, locals' perception toward mangroves forest and lastly their demographic characteristics of the households. The household survey was conducted by well-trained enumerators. During the household survey, the respondents were briefed on the objectives and purpose of the survey. Each interview lasted about 30 minutes.

Sampling

The sample size was estimated based on the number of a household living at the selected study site, in which the households' data was provided by the Land District Council Office. The sample size was determinedusing the simplified sampling formula from Yamane (1985) at 5% of the precision level. A total of 384 households were successfully interviewed during the survey (Table 1).

Table 3 Percentage of sampled households

Villages	Households	Sampled Households	Percentage (%)
Kampung Anak Air	150	21	5.5
Kampung Belukar	400	70	18.2
Kampung Kempadang	150	44	11.5
Kampung Peramu	900	80	20.8
Kampung Permatang Badak	60	20	5.2
Kampung Sungai Isap	120	43	11.2
Kampung Tanah Putih	150	41	10.7
Kampung Tanjung Api	180	35	9.1
Kampung Tanjung Lumpur	80	30	7.8
Total	2190	384	100.0

RESULTS AND DISCUSSION

Mangrove Forest Uses

The results of the study found that 36% of the respondents used the mangrove forest area in Sungai Kuantan. The purpose of using the mangrove forest area can be categorized into three: i) for own used/consumption, ii) income generation (fisherman, local fishmonger) iii) recreational fishing as a hobby during leisure time. Table 2 shows the use of mangrove forests by local community.

The results show that the majority of people use mangroves for recreational fishing during their leisure and free time, followed by for personal use and consumption, and for income generation respectively. This proved that mangroves in Kuantan not only provide goods (in terms of fisheries) but also amenities and services of great value to the local community. This finding also serves as a proof that it is importance to conserve and maintain the mangroves in Kuantan as the area provide a very significant benefit to people either to community lives nearby or to Kuantan's residents as well.

Table 4 The uses of mangrove forest by local community

Uses	N	Number of households uses mangroves area	Percentage of households uses mangroves area
For own used/consumption	384	51	13%
For income generation, such as fisherman, local fishmonger	384	38	10%
Recreational fishing during free/ leisure time	384	94	25%

Mangrove Forest Resources

The goods from the Kuantan mangrove forests that are often harvested by the villagers are *Macrobrachium rosenbergii* (Udang Galah), *Scylla serrata* (mud crab or locally known as ketam nipah), *Polymesoda expansa* (lokan), *Cerithidea obtusa* (siput sedut/Belitung) variety of fishes such as grouper (kerapu), sea bass (siakap), croaker (gelama) and many more. Table 3 shows the mangrove resources that are often harvested by locals.

Table 5 Mangroves resources

Mangrove resources	N	Percentage of households harvest	Uses
Udang Galah	384	41%	Sales and own use
Mud crab (*ketam nipah*)	384	36%	Sales and own use
Fishes	384	11%	Sales and own use
Molusca /seashell	384	8%	Own use
Others	384	3%	Sales and own use

Among the catch in the Kuantan River is *Udang galah*, where the price of it is from RM40-RM90 per kilogram. It is estimated that the total catch per trip is 4 kg during the season. In addition, various types of fish are caught in this area such as grouper, sea bass and thorn fish. However, most respondents did not sell seashells like lokan and siput belitung. Usually, locals consume it as daily food or give it away for free. The result proved that mangroves resources have provided one of the food sources for the nearby community not only for their daily food intake but also for them to sell and generate income.

Contribution of Mangrove towards Household's Income

Result found that the average monthly household income was RM2,882 per month (Table 4). There are two types of income which are either in form of cash or in-kind income. Cash income refers to income gained from wages, salaries, or business. Meanwhile, income in-kind can bein the form of provisions, such as consumption of mangroves resources as daily food sources or it can come in the form of property or an exchange of services. For this study, 92% of this community household's incomes were cash income and only 8% from the in-kind income.

Table 6 Households' monthly income

Types of income	RM/ month	Percentage (%)
Cash income	2,652	92
In-kind income	230	8
Average households' monthly income	2,882	100

The ability of Kuantan mangroves generates income for locals can be seen clearly in the sources of households' income, whether mangroves is one of the income sources and how much it contributes to the monthly income. The contribution can be from both cash and in-kind income. For example, mangroves related goods and products can be sold directly such as fresh fish and crab, or indirectly through processed foods such as fish ball, dried fish (ikan kering), and shrimp paste (belacan). The result shows at 31% of households' income is generated from the mangroves and its related sources. This finding shows that mangroves contributed to the livelihood of these nearby communities.

Table 7 Income generated from mangroves

Average income generated from mangroves and its related sources	
Average monthly income generated	RM 862
Percentage income generated	31%

CONCLUSION AND POLICY IMPLICATION

In conclusion, mangrove forests in Kuantan not only provide goods but also amenities and services that give great value to the local community. Therefore, it is important to conserve and maintain the mangroves at Kuantan as the area provides a very significant benefit to people. The results of this study act as evidence that Sungai Kuantan mangrove forest is able to generate income hence, contributing to the livelihood of these coastal communities.

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THE ECONOMIC, SOCIAL, AND ENVIRONMENTAL IMPACTS OF RESTORATION, RECLAMATION, AND REHABILITATION PROGRAM OF DEGRADED FOREST AREAS IN PENINSULAR MALAYSIA

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In December 2014, massive floods struck Malaysia, making it one of the deadliest natural disasters in the country's history. The floods not only impacted the economy but also changed the social structure and caused environmental degradation. The occurrence of a series of disasters prompted the creation of a program to restore, reclaim, and rehabilitate degraded areas in Peninsular Malaysia (3RSM), which was implemented by the Forestry Department Peninsular Malaysia (JPSM). A total of 189,000 trees of various local species were planted on 1,640 ha of permanent forest reserves that had been degraded by floods, landslides, and encroachments. In addition, the forestry department was given funding to improve eleven nurseries to assure a consistent supply of high-quality planting materials. The present water quality information is also provided by evaluating the water quality index in the planting regions. The 3RSM program's impact analysis was conducted to measure the advantages gained by the stakeholders. Three Focus Group Discussions (FGDs) were held to obtain stakeholders' opinions and perceptions on the current and expected impacts of the program . In addition, eleven nurseries were visited, and 28 seedling recipients from the 3RSM program were surveyed. The findings from FGDs identified a total of 122 positive impacts out of 172 impacts including economic, social, and environmental impacts. About 50% of the impacts were classified as having an intense impact on the stakeholders. The planting trees program under 3RSM managed to attract 7,410 participants from communities, education institutions, government agencies, private companies, and non-government organizations involved with the program. They believed that the program could increase their awareness of the importance of trees and improve the landscape and beauty of the areas. Currently, the research is confined to the 3RSM program's current effect evaluation and predictions. The 3RSM program, which focuses on tree planting as its primary activity, will take much longer to evaluate. Determining the actual impact of replanting is not yet possible and will take a longer time because the seedlings planted are still young. Further comparative research of the current and post-impact should be conducted to determine the actual impact of the 3RSM programme.

Keywords: 3RSM Programme, degraded forest, stakeholder perception

INTRODUCTION

In December 2014, massive floods struck Malaysia, making it one of the deadliest natural disasters in the country's history (Ibrahim 2015). Natural disasters that occurred in 2014-2015 cost the country billions of ringgits in losses. The floods not only impacted the economy but also changed the social structure and caused environmental degradation (Lee & Pradhan 2007; Augustine 2016; Sarina & Rahimah 2017). Realizing the importance of trees and green areas in reducing the impacts from those disasters, the government approved a program for restoration, rehabilitation, and reforestation of degraded forest areas in Peninsular Malaysia, also known as 3RSM under the Eleventh Malaysia Plan. This 3RSM program was initiated by the Forestry Department of Peninsular Malaysia (FDPM). A total of 189,000 trees of various local species were planted on 1,640 ha of permanent forest reserves that had been degraded by floods, landslides, and encroachments (JPSM, 2017). In addition, the forestry department was given funding to improve eleven nurseries to assure a consistent supply of high-quality planting materials. These nurseries provide seedlings to various stakeholders such as municipal councils, private companies, and schools. This paper will be highlighted the impacts of the program on the social, economic, and environmental aspects to stakeholders, particularly local communities. The stakeholders' perception of the restoration program that has been carried out and the benefits obtained by the stakeholders through the program will be identified.

MATERIALS AND METHODS

A Focus Group Discussions (FGDs) were held in three (3) places in Janda Baik, Kuala Kerai, and Kota Bharu to obtain the views and perceptions of stakeholders on the current and projected impact of the 3RSM program. A total of 205 stakeholders participated in these FGDs consisting of 61 participants in Janda Baik, 92 in Kuala Kerai dan 52 in Kota Bharu. Besides, a total of 11 nurseries were visited to obtain detailed information. A survey was also conducted on 28 recipients of seedlings under the 3RSM program. The recipients were schools, universities, Local Authorities, government agencies, Village Community Representative Councils (MPKK), Non-Governmental Organizations (NGOs), and private bodies. Evaluation of the water quality index was conducted in the planting regions.

RESULTS AND DISCUSSION

The findings from FGDs identified a total of 172 impacts which consist of 48 economic, 43 social, 73 environmental impacts, and 8 impacts which are a combination of two aspects. About 50% of the impacts were classified as having an intense impact on the stakeholders. Based on The Economics of Ecosystem and Biodiversity (TEEB 2010), these impacts can be classified into four (4) functions of ecosystem services as shown in Table 1. These findings showed that the 3RSM program provides the highest impacts on the cultural function of ecosystem services, followed by provisioning and supporting services. Planting activities near rivers may have a direct impact on water quality, which attracts eco-tourism and recreational activities and improve the socioeconomic condition of local communities. Therefore, it becomes the main concern among the local communities. Apart from that, water quality index assessments for Sungai Benus in the Lentang Forest Reserve were also conducted to obtain information on the current water quality at the 3RSM project location. The activity involved 11 sampling locations covering six planting blocks with a total area of almost 100 ha. Findings from the Water Quality Index (IKA) showed that the rivers are in a good condition. Reforestation activities in the study areas were expected to reduce erosion and sedimentation impacts.

Table 1 Number of impacts based on functions of ecosystem services

The function of ecosystem services	Number of impacts
Provisioning	38 (22)
Habitat	17 (10)
Supporting	37 (21)
Culture	80 (47)
Total	**172 (100)**

Note: Values in parentheses are percentages
Source: FGDs

Eleven nurseries in Peninsular Malaysia have benefited from a total allocation of more than RM3.5 million. It impacted nurseries with 50% of the existing nurseries facilities being upgraded. Besides, 63% of nurseries were able to increase their capacity in producing seedlings to be given to recipients. Lists of nurseries with their capacity and current utilization are shown in Table 2. Based on upgraded facilities, these nurseries should be able to increase their production of seedlings because currently all nurseries are not fully utilizing their area.

Table 2 Lists of nurseries and their capacity

No	Nurseries	Area (ha)	Current number of seedlings (% of utilisation)	Total Species	Maximum capacity of seedlings
1	Tapak Semaian Bukit Gambir	0.34	1,416 (11)	18	13,000
2	Tapak Semaian Manong	5.70	31,866 (31)	57	100,000
3	Tapak Semaian Mantin	5.00	11,500 (14)	34	80,000
4	Tapak Semaian Changlun	1.84	15,000 (38)	30	40,000
5	Tapak Semaian Sungai Buloh	3.40	22,607 (23)	87	100,000
6	Tapak Semaian Lentang	1.70	130,000 (36)	111	360,000
7	Tapak Semaian Terla B	0.30	4,190 (21)	25	20,000
8	Tapak Semaian Rotan Tunggal	0.38	6,960 (46)	77	15,000
9	Tapak Semaian Bukit Batu Tapong	1.30	31,000 (19)	20	160,000
10	Tapak Semaian Semerak	4.00	3,598 (9)	31	40,000
11	Tapak Semaian Chalok	4.45	127,538 (85)	105	150,000

Note: Values in parentheses are percentages
Source: Survey of nurseries

A total of 5238 seedlings from 62 species were given to recipients for tree planting activities. The 3RSM tree planting program managed to attract 7,410 participants from communities, education institutions, government agencies, private companies, and non-government organizations involved with the program. They believed that the program could increase their awareness of the importance of trees and improve the landscape and beauty of the areas. Based on the survey, there is one school (Sek Keb Felda Lui Selatan) was received the first prize winner for its efforts towards the environment namely Johan Sekolah Lestari Session 2018/2019 at the National level. This school has received the seedlings from the 3RSM activity. The findings showed that 29% of recipients perceived that planting activities are successfully providing a beautiful landscape. About 18% of the respondents agreed that degraded land is utilised and managed very well with planting activities. However, 18% of recipients felt that receiving the seedlings still not achieving their objectives because the trees are still small and not functioning in shading and cooling the areas.

CONCLUSION AND RECOMMENDATIONS

Most stakeholders (including nurseries, seedling recipients, communities nearby replantation areas, and related agencies) agreed that the 3RSM program is benefited them and should proceed in the 12^{th} Malaysian Plan to reduce the losses impacts from natural disasters. However, there are areas for improvement for this program in the future as follows:

1. Increase consultation with local communities before starting the replantation program to increase awareness and willingness to protect and co-manage the areas
2. Increase engagement and involvement of the communities with the program as the source for side income
3. Technical advisory and surveillance visits to seedlings recipients to ensure the survival of planted trees
4. Selection of tree species which gives economic returns to communities such as durians, bamboo, and others

Overall, the impact study gives a bigger picture to the government in assessing the appropriateness of the number of funds invested for the 3RSM program. At the same time, the results of studies and observations conducted can provide input to the implementer in evaluating the effectiveness of the program conducted. The research approach provides a platform for stakeholders to present their views directly through Focus Group Discussions (FGD) while interviews through surveys to direct beneficiaries during the project can provide immediate input on the acceptance of stakeholders involved in the 3RSM program. This input benefits the implementing agencies in improving the implementation of such programs in the future. Currently, the impact study is limited to the assessment of the current and expected impact of the 3RSM program. The 3RSM program with tree planting as the main activity requires a longer time to allow the real impact to be assessed.

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FORESTRY BIOTECHNOLOGY

ESTABLISHMENT OF *SENNA ALATA* BREEDING STOCKS PLOT FOR FUTURE BREEDING PROGRAMME

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Senna alata (L.) Roxb. or locally known as gelenggang is an important medicinal and ornamental flowering tree from the family of Fabaceae. This plant can grow up to 12 m high and can be found in tropical countries with warm and humid environments such as Africa and Southeast Asia. *Senna alata* leaf extract has been reported to have various pharmacological activities including antibacterial, cytotoxicity, anti-inflammatory, antidiabetic, antihepatotoxic, hepatoprotective effect, antiseptic, antiviral, and exhibited strong DPPH radical scavenging activities. Due to this, therefore, under the 11th Malaysian Plan project, plant breeders from Plant Improvement Programme, Forest Research Institute Malaysia (FRIM) have taken an initiative to collect and plant this species in a breeding stocks plot located in FRIM, Kepong. This paper highlights the processes undertaken for collecting mother plants, the establishment of breeding stocks plots, and the germination activity of *S. alata* mother plants. Evaluation of their growth performances 12 months after planting is also highlighted. This is only an early phase in developing a breeding programme prior to any screening for the high-quality individual. The output of this study is believed to be very useful for future references and guidelines in producing a new variety.

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Keywords: Collection, growth performance, screening activities, plant breeder

INTRODUCTION

Senna alata also known as *Cassia alata*, is a widely distributed herb of the Fabaceae family. In Malaysia, it is known as gelenggang or daun kurap. Elsewhere it is commonly known as candle bush, Christmas candle, craw-craw plant, acapulo, ringworm bush, or ringworm plant. This shrub originated from Argentina, and currently can be found in Asia and Africa (Bradley et al. 2019). It is a small tree and can reach up to 1 - 2 m heights and has greenish branches. This plant is easily identified from its morphological characteristics. It has pinnate leaves, oblong-elliptical with rounded corners leaves, large inflorescence, and orange-yellow flowers. The fruit is tetragonal, winged pods is black, glabrous, and up to 50 quadrangular seeds (Globinmed 2020).

In Ayurvedic, Sinhala, Chinese, and African traditional medicine, various parts of *S. alata* are used in therapeutic activities. In northern Nigeria, a decoction of stem, leaf, and root is used to treat wounds, skin respiratory tract infections, burns, diarrhoea, and constipation (Uwazie et al. 2020). In Malaysia, fresh leaves of the plant are used to treat skin rashes, mycosis, and dermatitis. The frequent use of *S. alata* leaves is more than that of roots, and flowers. Whereas in Nigeria the plant has been processed into capsules, pellets, and tea for preventing diseases and maintaining good health (Oluwole et al. 2020). *Senna alata* has been reported to have a variety of bioactive compounds. The major compounds found are kaempferol and glycosides (such as kaempferol-3-O-gentiobioside and kaempferol-3-O-β-d-glucopyranoside) (Naowaboot & Wannasiri 2016). This compound has contributed to various pharmacological activities such as anti-inflammatory, antimicrobial, anti-obesity, anti-malarial, and hepatoprotective activity (Ranjanie et al. 2019). Other chemical constituents found are phenolics (rhein, chrysaphanol, kaempferol, aloeemodin, and glycosides), anthraquinones (alatinone and alatonal), fatty acids (oleic, palmitic, and linoleic acids), steroids, and terpenoids (sitosterol, stigmasterol, and campesterol) (Liu et al. 2009).

Looking at the pharmaceutical potential of the species, under the 11th Malaysia Plan Project an initiative has been taken by plant breeder of Forest Research Institute Malaysia (FRIM) to collect mother plants of this species randomly from four wild populations in Peninsular Malaysia. Morphological characteristics of all mother plants were measured and recorded. This paper highlights the processes undertaken for collecting mother plants, the establishment of breeding stocks plots, and the seed germination rate of the species. Evaluation of their growth performances 12 months after planting is also highlighted. This is only an early phase in developing a breeding programme prior to any screening for high-quality individuals. It is expected that at the end of the project, high yielding individuals with high biochemical compounds will be identified and mass produced for the benefit of herbal industries.

MATERIALS AND METHODS

Collection of *Senna alata* Genotypes from Wild Populations

A total of 120 mother plants of *S. alata* were identified from four populations in Peninsular Malaysia comprising i) Kuala Selangor, Selangor ii) Raub, Pahang, and iii) Ketereh, Kelantan and iv) Kuala Pilah, Negeri Sembilan. A few phenotypically superior genotypes showing good growth, full of branches, superior height, and diameter were selected for the study. The stumps of selected plants were dug out whereas the matured fruit pods were brought back to FRIM, Kepong (Figure 1). These materials were transplanted into polybags and the seeds were used for germination. All collected stumps were labelled differently such as BG1-BG30 (Kuala Selangor, Selangor), CG1-CG30 (Raub, Pahang), DG1-DG30 (Ketereh, Kelantan), and NSG1-NSG30 (Kuala Pilah, Negeri Sembilan).

Figure 1 Collection and preparation of *S. alata* stumps from four populations

The topographic information such as coordinates, altitudes, dates of assessment, and morphological data were also recorded. The data are shown in Table 1 and Table 2.

Table 1 Topographic information of *S. alata* mother plants from four populations

Populations	Mother Plants Code	GPS Points	Altitude
Kuala Selangor, Selangor	BG	N3 21’51.6 E101 19’21.5	9 m
Raub, Pahang	CG	N3 56’28.2 E101 50’45.0	135 m
Ketereh, Kelantan	DG	N5 34’68.9 E102 13’89.3	48 m
Kuala Pilah, N. Sembilan	NSG	N2 44’33.9 E102 08’88.7	115 m

Table 2 Morphological data of *S. alata* mother plants from four populations

Populations	No. of clumps	Height (m)	Diameter (cm)	Leaf length (cm)	Leaf width (cm)
BG	1-3	1.0-4.2	1.2-6.8	10.0-16.3	4.0-7.8
CG	1-5	0.5-5.3	0.7-7.5	10.5-17.2	3.5-6.5
DG	1-8	1.02-2.56	1.0-5.4	10.2-18.5	4.4-7.8
NSG	2-9	1.03-2.97	1.0-4.0	9.3-17.4	3.8-7.5

Maintenance of *Senna alata* Stumps at Nursery

It is vital to maintain the stumps of *S. alata* at nursery conditions in order to make sure that the plants get appropriate treatment and have a higher percentage of survival. It is also the process to understand their requirements such as fertilization requirements and water supply. All stumps were planted in polybags with the size of 10” x 10” and maintained under 50% shades at the nursery for three months before being transferred to field planting. All plants were irrigated with a water sprinkler system twice a day (Figure 2).

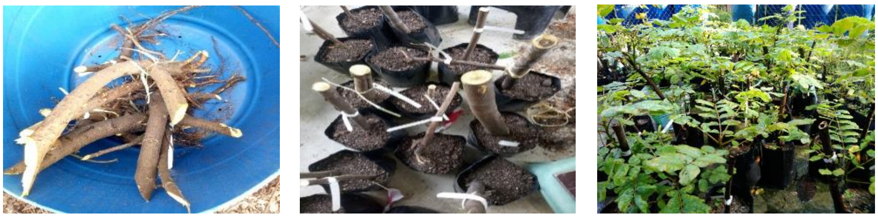

Figure 2 The stumps of *S. alata* were planted and grown at FRIM’s nursery under 50% shades before transferred for field planting

Establishment of Breeding Stocks Plot

After three months, all the grown stumps were planted in a breeding stocks plot located at FRIM, Kepong with a plot size of 20 m x 28 m. The planting distance used was 1.5 m x 1.5 m. CRP and organic composts were applied in each of the planting holes. The growth data of the plants at the planting plot were collected monthly. Some of the parameters measured were height (cm), diameter (mm), and the size of the crown (X and Y) (Figure 3). Survivability of the plants was also recorded after 12 months of planting. The survived mother plants with good phenotypic characteristics were selected and tagged for future screening work.

Figure 3 Planting process and measurement of growth data of *S. alata* in a breeding stocks plot

Germination of *Senna alata* Seeds

The performance of the mother plants in a breeding stocks plot was also evaluated in terms of their germination rate. Seeds were extracted manually and air-dried at normal temperature (Figure 4). Only complete dried seeds were chosen for germination studies. A total of 100 *S. alata* seeds from each of 12 selected mother plants were sown in a germination tray with 100% sand medium in FRIM's nursery. The tray was placed under 50% shade and equipped with a complete irrigation system. The mist sprinkler was set up for 1 minute three times per day. Data on germinated seeds were collected every two days.

Figure 4 Seeds of *S. alata* were extracted manually from the matured pot

RESULTS AND DISCUSSION

Growth Performance of *Senna alata* Mother Plants

After one year planted at the breeding stocks plot, it was observed that only twelve (12) mother plants of *S. alata* showed good phenotypic characteristics and were suitable to be selected for future screening work. It was observed that most of these plants recorded a height of more than 1.0 m with a diameter range of between 1.2-5.8 m. In terms of leaf characteristics, the plants recorded more than 10.0 cm of leaf length, whereas more than 5.0 m for leaf width. The growth performance for selected mother plants is shown in Table 3. All mother trees have different viability due to different genotypes and phenotypes (Zobel & Talbert 1984).

Table 3 Growth performance of twelve mother plants of *Senna alata*

Mother Plants Code	No of Clumps	Height (m)	Diameter (cm)	Leaf Length (cm)	Leaf Width (cm)
BG20	6	3.0	5.80	11.7	5.5
BG24	2	2.0	3.10	11.0	5.4
BG25	1	1.9	2.20	11.3	5.4
BG29	3	1.2	2.40	10.6	5.3
BG30	2	3.0	3.20	11.9	6.2
NSG12	2	1.4	1.20	14.5	5.7
CG30	5	2.1	2.80	15.2	5.3
CG32	3	2.5	1.60	15.2	5.7
DG23	2	1.9	1.50	17.8	7.5
DG21	4	1.4	1.20	12.0	6.4
BG6	4	1.8	3.20	12.9	5.5
BG17	1	1.2	2.20	10.9	5.0

Seed Germination Rate of *Senna alata*

Results in Figure 5 showed that seeds from mother plant BG29 gave a higher number (>90%) of germination compared to others after two days of germination. A previous study reported that the seeds of *S. alata* after water-soaked for 24hr displayed a better germination percentage of around 76.80% (Thirupathi 2012). The number of seeds germinated increased drastically from 22 to 90 after four days of germination. Besides BG29, the highest germination rate was also recorded by mother plants DG23 and BG24 with a percentage of almost 40%. Whereas other seeds showed a germination rate below 30%. Mother plant CG30 recorded the lowest germination rate (<5%) compared to others, which might be due to the less viability of the seeds. The results indicated that only seeds of *S. alata* from genotype BG29 have the highest seed viability. This finding showed that this plant has a high potential to be selected as good parent material for the future breeding programme. In addition, according to Kumar et al. (2008), seed characteristic such as seed length of different provenance is important criteria in order to produce maximum germination percentage. Besides that, seeds sources from a different agroclimatic zone also gave an effect on the seed viability. According to Zobel & Talbert (1984), the ensuring of seed production is coming from good genotype individuals. The mother trees which are pollinated by good genotype individuals and minimal selfing or breeding will then produce vigour and good generation.

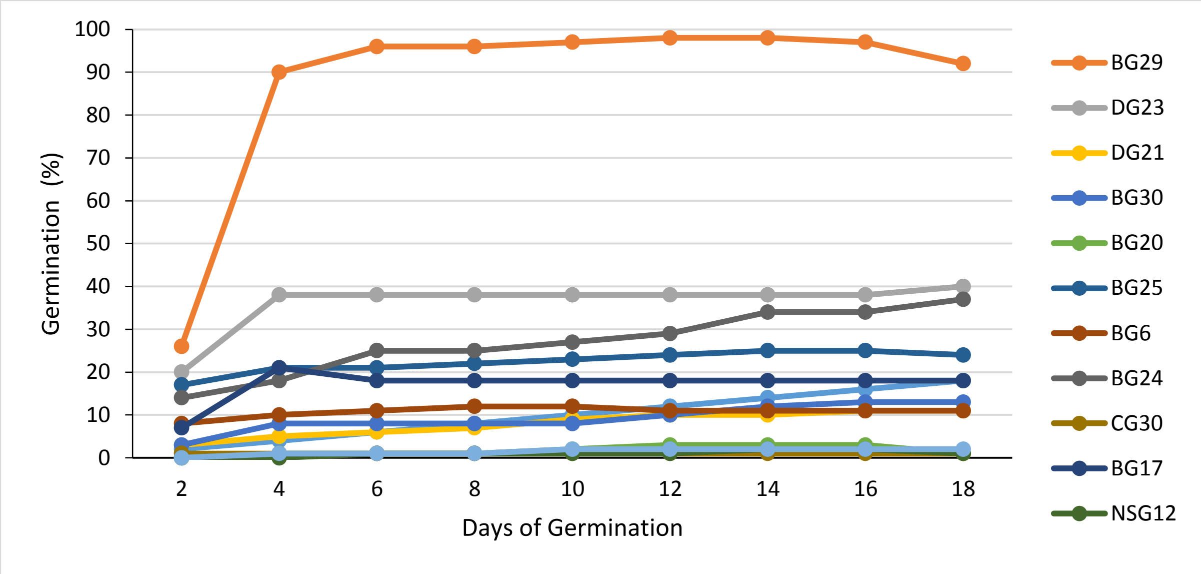

Figure 5 Germination rate of *Senna alata* seeds collected from the established breeding stock's plot

CONCLUSION

The established breeding stocks plot is a method of genetic conservation and to sustain the production of quality planting materials in the future. In addition, seed germination screening provides a great opportunity for the tree breeder to screen and capture natural variation, besides providing information on the raw material for breeding. In conclusion, outputs from the study are beneficial to the plant breeders in the aspect of producing new variety and to herbal industries in producing high-quality herbal products.

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EFFECTS OF DIFFERENT SEEDLING HEIGHTS AND DIFFERENT GROWING MEDIUM ON THE GROWTH OF *BAECKEA FRUTESCENCE* WILDINGS

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Baeckea frutescens is a heather-like shrub under the family of Mrytaceae and is locally known as cucur atap. This species is found along coastal sandy areas of Peninsular Malaysia, Sumatra, Southern China, and Australia. The species is being used as a natural remedy for curing various health problems and claimed to have potential anti-bacterial, anti-dysentery, anti-pyretic, and diuretic properties. It is also believed that the species is effective in treating influenza, coryza, epistaxism sunstroke, fever, headache, measles, colic, jaundice, and irregular menstrual cycles. Due to the benefits and its potential, researchers from Plant Improvement Programme, Forest Research Institute Malaysia (FRIM) have attempted to conduct a collection of *B. frutescens* wildings from four different areas in Peninsular Malaysia. Collection of these planting materials is essential due to difficulty in getting seeds and slow germination rate. Previous work on the appropriate technique of collection of *B. frutescens* wildings for production of planting stocks at nursery stage is very limited. Therefore, this study was carried out to solve the problem by collecting wildings at different heights of 0.5, 1.0, and 2.0 feet. These wildings were brought back to FRIM and transplanted into polybags with a mixture of soil, sand, and compost as the growing media. The growth performance of different wildings heights was monitored and recorded in terms of their survival and growth. Wildings with 0.5 feet produced the best survival of 70% as compared to those with 1.0 and 2.0 feet height. Soil media experiment showed that a ratio of 1:2 (topsoil: sand) produced the highest survival rate of 67%, 0.56 feet average heights and 1.27 mm diameter. The output of this experiment is believed to be very useful for future references and to provide a guideline for the collection of the species.

Keywords: *Baeckea frutescens*, wildings height, growth medium, planting stocks

INTRODUCTION

Baeckea frutescens is a shrub heather-like shrub or a small evergreen tree under the family of Mrytaceae. In Malaysia, this native species is known as cucur atap (MyBIS). This tree is 1– 6 m tall with a trunk up to 10 cm of diameter with greyish brown, vertically fissured bark and tends to flake. The leaves are in opposite arrangement and needle-like, seemingly in clusters at condensed nodes. The flowers are too small, and the reproduction is bisexual. The species can be reproduced by seed, but the germination times take about 12 months for the seedlings to fully develop as a plant. To our knowledge, other propagation methods such as cuttings have not been reported.

In Malaysia, *B*. *frutescens* can be found on mountain tops, quartz ridge, and sandy coast of the eastern parts of Peninsular and distributed along the coastal areas of Southern China and Australia (Kochummen & Ng 1978; Wong et al. 2010). This species is used as a natural remedy in curing various health conditions. Traditional medicinal properties of this species were reported in influenza, dyspepsia, jaundice, dysentery, measles, and irregular menstrual cycles (Adib et al. 2014). The bioactive constituents were shown to have potential anti-bacterial, anti-dysentery, anti-pyretic, and diuretic activities (Shahruzaman et al. 2019). Furthermore, their study also showed that this species can be used as an effective agent that regulates metabolic reprogramming in breast cancer. This study used branches extracts from *B*. *frutescens* and the results showed potent selective cytotoxic activity against MCF-7 cells compared to MDA-MB-231 cells after 72 hours of treatment by inhibiting glucose consumption in breast cancer cells.

Besides that, *B*. *frutescens* also has the potential to be used as anti-gout remedies. Research conducted by Fadzureena et al. (2013) showed that active compounds in the leaves and stems of *B. frutescens* extracts were effective in inhibiting the uric acid formation and promoting uric acid secretion. Thus, effective against gout attack prevention.

Based on the pharmacological activities of this species, researchers from Forest Research Institute Malaysia (FRIM) have taken the initiative to collect and conserve this species for future uses. Thus, the focus of this research was on wildings because of the difficulty in getting their seeds, and most of *B*. *frutescens* were damaged due to heavy collection from bonsai collectors. This paper highlights the process of wilding collection of different heights, maintenance activities, and their growth performances at the nursery stage. The effects of growth performance of different wildings height of *B*. *frutescens* and different growing media applied at nursery stage were discussed. The results will be used for the next collection for this species at different locations.

MATERIALS AND METHODS

Wilding Collection of *Baeckea frutescence* from Nilai, Negeri Sembilan

Ten phenotypically superior trees of *B*. *frutescens* with good growth, full of branches, and superior height and bole diameter in Nilai, Negeri Sembilan were identified and selected as mother trees prior to the collection of wildings. This was done to ensure that the collected wildings have a good phenotype as their parent trees. Thus, ten phenotypically superior trees of *B*. *frutescens* were selected from this area (2.81103, 101.77587). Ten superior trees of *B*. *frutescens* were tagged as NCA 30, NCA 13, NCA 16, NCA 28, NCA 29, NCA 18, NCA 11, NCA 15, NCA 26, and NCA 25 (Figure 1). Different heights of wildings such as 0.5, 1.0, and 2.0 feet height were collected from the floor. The wildings were pulled out carefully using a small shovel. The root ball was made for each wilding to avoid any root damage. After that, all wildings were packed carefully and transported back to FRIM for further treatments.

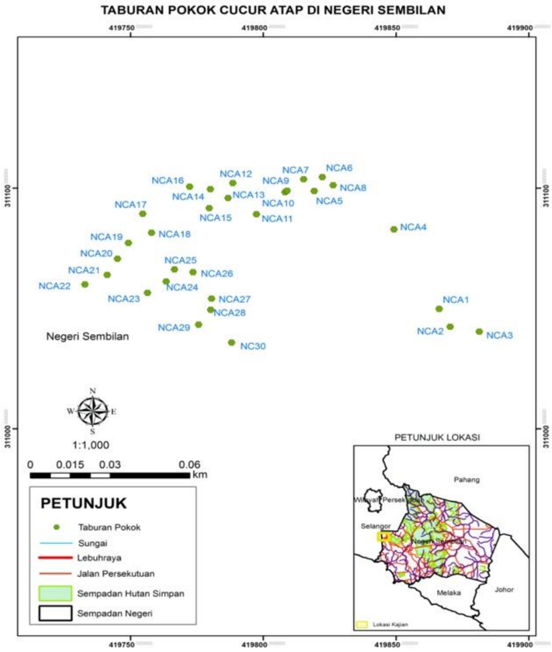


Figure 1 Area of selected wildings for *Baeckea frutescens*, Nilai, Negeri Sembilan

Plant Maintenance at Nursery

The collected wildings of *B. frutescens* were potted into polybags with the size of 6" x 8". The potting media used was the mixture of soil and sand at the ratio of 1:2 (Figure 2). At the initial stage, the plants were acclimatized at FRIM's nursery with 50% shade for three months. After that, they were transferred to the open area for two months in order to go through the process of hardening. The plants were well maintained in which watering, weeding, and fertilization were regularly conducted.

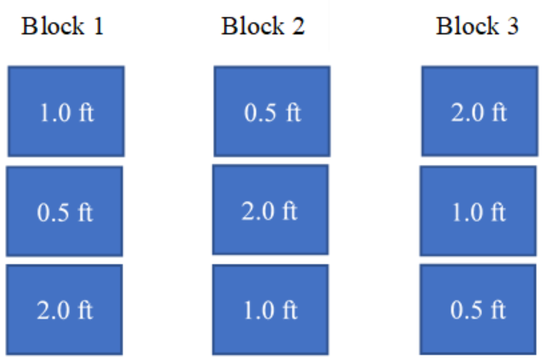
Different height of *B. frutescens* were measured

Wildings of *B. frutescens* were potted into polybags with the size of 6" x 8"

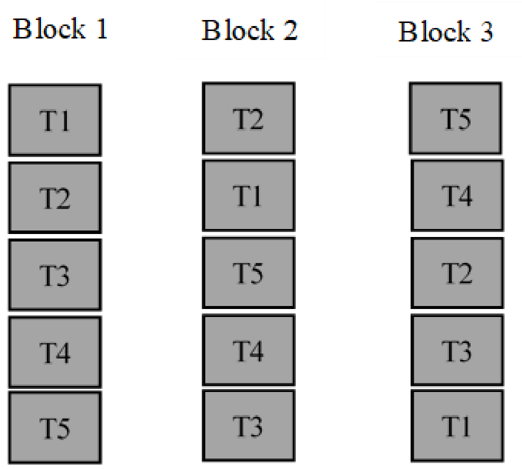
Figure 2 Wildings of *Baeckea frutescens* were potted and maintained at Nursery stage

Nursery Experiment

An experiment on the survival of different heights of *B. frutescens* was conducted and a total of 30 wildings for every 0.5, 1.0, and 2.0 feet were laid out in a complete randomized design (CRD). The survival of the wildings was measured monthly intervals up to six months.



Then, the best height of wildings that produced the best performance was chosen for different growing media experiments. The mixture of growing medium used were Treatment 1 (T1) topsoil: sand (1:2); Treatment 2 (T2) topsoil: compost: sands (1:2:1); Treatment 3 (T3) topsoil: coconut husks: sands (1:2:1); Treatment 4 (T4) topsoil: coconut husks: sands (1:1:2) and Treatment 5 (T5) 100% sands.



RESULTS AND DISCUSSION

Results showed that 0.5 feet of wildings of *B. frutescens* gave the highest survival rate than those with 1.0 and 2.0 feet (Figure 3). The survival rate of wildings with 0.5 feet height was at 70% followed by 1.0 feet height at 51.3% and 2.0 feet height at 43.8%. This was probably due to lower water loss through the transpiration process in a smaller size of wildings compared to the bigger size of wildings. Another reason might be due to the number of leaves recorded by 0.5 feet wildings were not as much as the number of leaves found in 1.0 feet and 2.0 feet of wildings that contributed to the transpiration process in the plants. However, many other environmental factors such as soil, shading, temperature, and humidity at the nursery stage might also affect the wildings survival rate as reported by Djers et al. (1998) in their study.

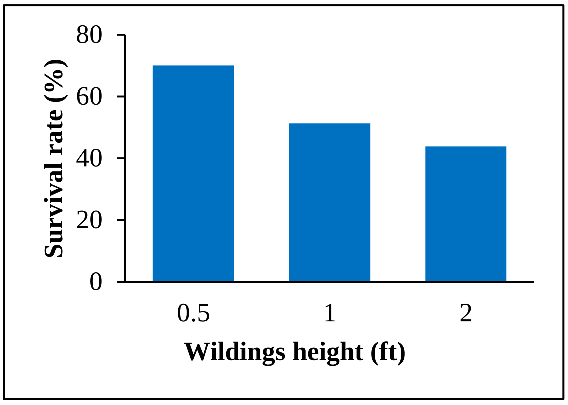


Figure 3 Survival rates of different wildings of *Beackea frutescens* at the height of 0.5, 1.0 and 2.0 feet

The growing medium experiment showed that Treatment 1 (1 topsoil: 2 sands) produced the best result on the growth of *B. frutescens* wildings with 67% of survival rate (Table 1). Treatment 1 produced an average height of 0.56 ft which was significantly different from other growing media treatments (T2-T4). In terms of collar diameter, T1 also showed the highest value of 1.27 mm as compared to other treatments. Meanwhile, a medium containing a combination of compost and coconut husk showed the lowest survival rates of 26 to 41%. Sawdust and coconut husk are found to have a high capacity in holding moisture and may contribute to low air porosity. Under this condition, the plants ability to receive sufficient air and oxygen is limited during the respiration process (Buwalda et al. 1995). Whereas T5 (control) indicated the lowest survival rate. In terms of average height and collar diameter, the results revealed that there was not significantly difference between Treatments 2, 3, 4, and 5. The survival rate of the plants may be also influenced by the factor of soil structure and pH value. For example, the medium with sand only tends to drain the water quickly as the pores between the particles are large compared with the medium sand that mixed up with topsoil. The structure is better in supporting the root penetration and absorption of enough water for the plant growth (Hartmann & Kester 1983).

Table 1 The growth and survival rates of wildings in different media types

Types of Media	Survival rate (%)	Height (ft)	Diameter (mm)
T1 1 topsoil : 2 sands	67.3a	0.56a	1.27a
T2 1 topsoil : 2 compost : 1 sands	41.3b	0.51b	0.49b
T3 1 topsoil : 2 coconut husks : 1 sands	37.8bc	0.52b	0.30b
T4 1 topsoil : 1 coconut husks : 2 sands	25.7bc	0.51b	0.58b
T5 100% sands	17.0c	0.50b	0.32b

*means followed by the same letter is not significance at 0.05 level of significant

CONCLUSION

In conclusion, different wildings heights of *B. frutescens* have an effect on the growth and survival rate at the nursery stage. The common practice of growing medium mixture (1 topsoil: 2 sands) was the best medium for growing the wildings. However, other studies on the environment, soil, shading, temperature, and humidity at the nursery stage should also be carried out to identify the best factors that enhance the growth of *B. frutescens* wildings at the nursery stage.

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EFFECTS OF DIFFERENT GROWTH MEDIA AND GROWTH CONDITION ON STEM CUTTINGS OF *CHROMOLAENA ODORATA*

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Chromolaena odorata L. (Siam weeds) is commonly known as pokok kapal terbang in Malaysia belongs to the family Asteraceaea. Traditionally, fresh leaves or a decoction of *C. odorata* have been used by tropical countries for the treatment of leech bites, soft tissue wounds, burn wounds, and skin infections. Scientific studies on the effects of *C. odorata* leaf extract towards wound healing had been conducted by researchers and it shows positive results. Looking at the potential medicinal value, it is a necessity for the plant breeder to come out with high quality planting materials of this species for industrial usage. The propagation technique plays an important role to ensure the sustainability of high-quality raw materials. Therefore, this study aimed to identify the suitable condition for growing the stem cuttings of *C. odorata.* Two different growth media such as M1- 2 soil: 1 sand and M2-1 soil: 1 sand were tested and the stem cuttings were grown in two different conditions, C1: greenhouse; C2: greenhouse with enclosed propagation chamber. The survival rate of the cuttings was recorded weekly whilst the rooting performances were measured at week 4. Stem cuttings were grown in M1- 2 soil: 1 sand shows 100% survivability at greenhouse condition whereas cuttings grown within enclosed propagation chamber gradually reduce survivability after two weeks of cuttings. Therefore, this study suggests the stem cuttings of *C. odorata* should be grown in M1-2 soil: 1 sand growing media at greenhouse condition. The findings from this study are vital for breeders and herbal propagators for the mass production of *C. odorata* in the future.

Keywords: *Chromolaena odorata,* stem cutting, macropropagation, mass production

INTRODUCTION

Chromolaena odorata L. belongs to the largest family of flowering plants which contains about 900 genera and 13,000 species (Akinmutimi & Akufo 2006). This plant is native in North America and has been introduced to South America, Tropical Asia, West Africa, and parts of Australia (Mc Fadyen & Skarratt 1996). This weed has a minimum of 10 years life span which grows 2-3 m in height with a straight, pithy, brittle stem that branches readily. The leaves are arrowhead-shaped that grow in opposite pairs along the stems and branches (Sirinthipaporn & Jraungkoorskul 2017). The roots are narrow and fibrous and generally reach 0.3 km in depth (Chakraborty et al. 2011).

It was reported that *C. odorata* is an aggressive competitor that suppresses young plantation, agriculture crops and grows on other vegetations (Azmi 2002). However, there was research showing that the species has a positive contribution to the agricultural sector. The leaves of *C. odorata* are used as an ingredient for formulating animal feeds especially in rabbit's diets where the nutrient profile is similar to a concentrated feed (Bamikole et al. 2014). The leaves are also claimed to have high nutritive values and have the potential to be used as protein supplements to ruminants (Apori et al. 2000).

Traditionally, fresh leaves or a decoction of *C.odorata* have been used by tropical countries for the treatment of leech bites, soft tissue wounds, burn wounds, and skin infections (Phan et al. 1998). Scientific studies on the effects of *C. odorata* leaf extract on wound healing had been conducted and showed positive results (Vaisakh & Pandey 2012). The leaves extract can also inhibit the growth of microorganisms in the wounds and help in forming new tissue cells (Phan et al. 1998).

This plant has a great potential to be commercialized in the pharmaceutical industry. Thus, researchers from Herb and Tree Improvement Branch, Forest Research Institute Malaysia (FRIM) have started the breeding studies on this plant for future planting stocks production. The present experiment was carried out to observe the effects of different growth media and growth conditions on stem cuttings of *C.odorata*. The finding from this study can be used as a guideline in the mass propagation of this plant in the future.

MATERIALS AND METHODS

Preparation of Stem Cuttings

Stem cuttings of *C. odorata* were collected from the sourcebush at Forest Research Institute Malaysia (FRIM). The stem part with two to three nodal segments was used as the cutting materials (Figure 1). The leaves were cut to about two-third of their original size in order to encourage root and shoot growth. The base of each cutting was applied with commercial rooting hormone Seradix (0.1% Indole Butyric Acid) using the basal quick-dip method. A total of 30 stem cuttings were used for each experiment.

Figure 1 Stem cuttings of *Chromolaena odorata* with the nodal segment

Preparation of Growth Media and Growth Condition

The stem cuttings treated with Seradix were immediately planted onto two sets of growing media containing mixture of; M1- 2 topsoil: 1 sand, M2- 1 soil: 1 sand. The experiment was conducted in a square based plastic pot (Length: 53 cm x Width: 40 cm x Height: 8 cm). The plants were kept in two growth conditions: C1- Open greenhouse, C2- Greenhouse with enclosed growing chamber. The greenhouses were installed with an automatic misting system that operated for 1 minute thrice a day (8.00 am, 12.00 pm, and 4.00 pm) to water the plants.

Assessment of Cuttings

The study was conducted for a total of 4 weeks and the measurement of the stem cuttings was conducted every week, including survival and rooting percentage, number, and length of roots per cutting. Any plants with their leaves and/or stems that turned brown were considered dead and their measurements were stopped. Analysis of variance (ANOVA) was conducted to compare each of the parameters measured between the different media and environmental treatments. Statistical analysis was conducted using SPSS version 22.

RESULTS AND DISCUSSION

Survival and rooting percentage: The stem cuttings were grown in 2 topsoils: 1 sand at open greenhouse (M1: C1) had the highest survival percentage at all weeks (100%) (Figure 2a). Stem cuttings treated in 1 topsoil: 1 sand in enclosed growing chamber (M2:C2) had the lowest survival percentage at week 2 (17%) and gradually dead after week 2. None of the cutting was rooted at week 1(Figure 2b). Most of the cuttings started to root at week 2. The stem cuttings treated with M1:C1 had the highest rooting percentage (100%) followed by M2:C1 (87%) and M1:C2 (13%).

Effects of growth media and growth condition on root development: There were no significant differences between growth media used and the growth condition on root development of *C. odorata.* Stem cuttings treated with M1:C1 produced the highest root number per plant (45.3±9.72) and root length (12.2 cm±1.52) whereas stem cuttings treated with M1:C2 produced the least root number per plant (25.8.±13.2) and root length (9.10cm±2.70) (Figure 3).

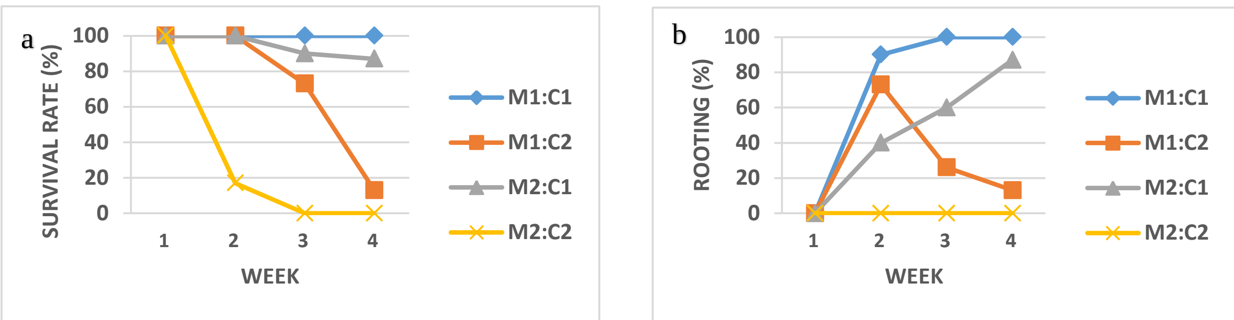

Figure 2 (a) Survival and (b) Rooting percentage of *C. odorata* stem cuttings treated with different growth media and growth condition over 4 weeks

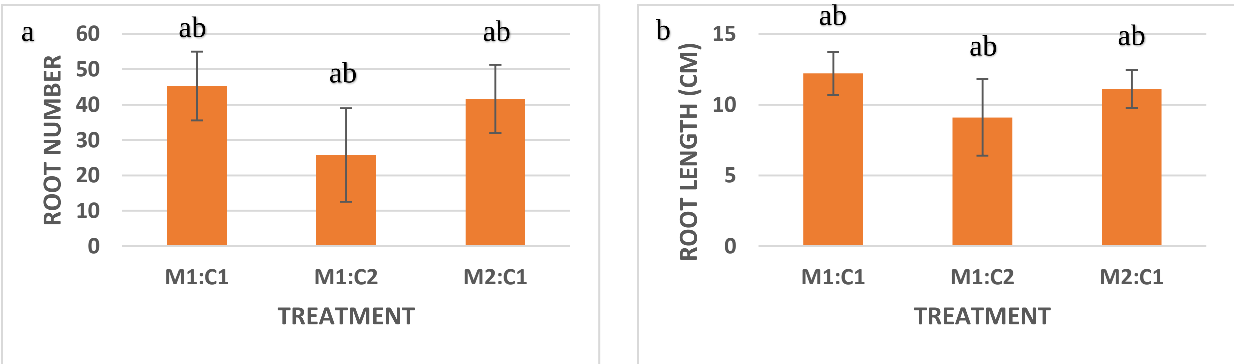

Figure 3 (a) Root number and (b) Root length of *C. odorata* stem cuttings treated with different growing media and growing condition at week 4. Values are Means±Standard Error (SE)

The successful rooting of stem cuttings could be influenced by many factors including the rooting medium, the environmental conditions as well as the physiological status of the stock plant itself (Arteca 1996). This study revealed that stem cutting grew in growth media M1:2 topsoil: 1 sand and placed at C1: open greenhouse gave 100 % survivability and 100 % rooting. The combination of sand and soil as the growth media in this study is to achieve high porosity and water retention while providing adequate aeration. Both materials are low-cost and easily available for the farmers to conduct the propagation of *C. odorata.* Stem cuttings of *C. odorata* preferred an open greenhouse environment over the enclosed propagation chamber. In the enclosed propagation chamber, the system is limited to low irradiance which limits the photosynthesis through the depletion of carbon dioxide during daytime hours (Rosenberg et al. 1992). In addition, high relative humidity that sustains the water potential within the enclosed propagation chamber may not be suitable for *C. odorata* as the stem will rot faster at such conditions. The present study reported no significant effects of the media and environment treatment on the root number and root length. The current work also suggested that more studies on different environmental conditions need to be conducted as this factor may improve the growth rate, number and length of root, and other parameters.

CONCLUSION

From the present findings, growing *C. odorata* stem cutting in 2 topsoils: 1 sand at open greenhouse system showed the highest survival rate, rooting percentage, and root length. The result may be important as a pioneer study on the macropropagation of this medicinal plant.

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POTENTIAL OF INTERCROPPING SELECTED HERBAL SPECIES IN COMMODITY PLANTATION

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Intercropping is defined as the agronomic practice of growing two or more crops on the same field at the same time. In this study, a model of the intercropping plot has been established at the R&D Centre, FELCRA Nasarudin Belia, Seri Iskandar, Perak with the aim to maximize the land use and increase the productivity and yield per hectare. Three herbal species namely *Labisia pumila* (kacip fatimah), *Citrus microcarpa* (limau kasturi), and *Cymbopogon citratus* (serai makan) have been introduced as intercrop species that can produce a yield in short to long term cycles. *Cymbopogon citratus* is a short-cycle crop that can be harvested after 6 months while *L. pumila* can be harvested after 9 to 12 months of planting. The maturity period for *C. microcarpa* is after three years of planting and it can produce yield up to 10 years. The return of investment (ROI) from a one-hectare intercropping plot is within three years with the benefit-cost ratio (BCR), RM1: RM 2.65 (for 10 years). This model plot has been commercialised to Koperasi Peserta Rancangan FELCRA Gugusan Bayai Berhad (KPRFGB) in Negeri Sembilan through Malaysia Social Innovation Program (MySI) funded by MOSTI. The demand for these herbal species is increasing annually and it is recommended for farmers to explore this intercropping model plot for additional income generation. Agriculture enthusiasts are welcome to collaborate with FRIM to expand the benefits of this program as well as to boost the country's herbal industry.

Keywords: Intercropping, *Labisia pumila*, *Citrus microcarpa*, *Cymbopogon citratus*, commodity plantation

INTRODUCTION

The instability of the palm oil industry in the past years has had a major impact on the national economy and indirectly affected the income of settlers. Therefore, the government and private sectors are working together to alleviate this problem. Various ideas and efforts have been undertaken mainly to secure the settler's income. The introduction of an intercrop planting system is among the good propositions where the settlers can generate multiple incomes while minimalising their operational costs. Among the alternative crops that have been introduced were those with a shorter maturity period such as roselle, pineapple, banana, figs, and jack fruit (Ayisy 2020).

In this study, herbal species were introduced as the cash crop in the intercrop planting model as they have a wide potential to the industry. Today, the herbal industry has become one of the economic engines in Malaysia agriculture. The Malaysian government has chosen the herbal industry as the first Entry Project Point 1 (EPP 1) for the nation's Agriculture New Key Economic Area. Under EPP 1, several high-value herbal products had been identified which can generate about RM 2,213.9 million in gross net income (GNI) for the nation by the year 2020. In Malaysia, herbs have been classified by product group as follows (Mohd Hafizudin et al. 2019):

i. Flavors and fragrance
    a. Cosmetics
    b. Perfumes
    c. Oil for aroma
    d. Essential oils
    e. Beverages
ii. Pharmaceuticals/Herbal
    a. Remedies/Drugs
    b. Vitamins/Supplements
iii. Health/Functional food
    a. Health food
    b. Herbal teas
    c. Herbal supplements
iv. Biopesticides
    a. Insect repellent
    b. Crops pesticide
    c. Household pesticide

Thus, selection of suitable herbal species for the intercrop planting system is important in order to achieve better return of investment and yield per hectare.

Species Selection

- ***Labisia pumila***

Labisia pumila or locally known as kacip fatimah is listed as one of the high-value herbals and is well recognized for containing phytoestrogen essential for women's health care. Forest Research Institute Malaysia (FRIM) has conducted R&D on plant breeding of this species for the past ten years and successfully produced one elite genotype with good growth performance and high yields through mass selection. This herbal plant is high in demand and the current small-scale plantation could not afford the needs of various industries. Therefore, large-scale planting of the high-yielding *L. pumila* genotype is urgently needed using intercropping planting system as an option for sustainable supply.

- ***Citrus microcarpa***

Citrus was the first fruit crop to be traded internationally due to its high economic and nutritional worth (Husni et al. 2021). Calamansi (*Citrus microcarpa*) is one of the most commonly utilised fruits in everyday life. Calamansi can be used in both food (seasonings, sauces, and other herbal preparations) and drinks (juice). The peels and leaves of calamansi produced essential oil through a distillation process. The essential oil of calamansi contains antioxidants and antimicrobials (Nguyen et al. 2018). Forest Research Institute Malaysia has produced a superior genotype of calamansi that contains a high percentage of linalool, a volatile compound related to antimicrobial and antifungal properties. Calamansi plantation could provide long-term income generation as this plant could sustain up to ten years.

- ***Cymbopogon citratus***

Cymbopogon citratus (lemongrass) is native to Malaysia and is grown throughout South East Asia. It is important in Asian cooking and has made its way onto countless ingredient lists for all sorts of dishes. Oil from lemongrass is widely used as a fragrance in perfumes and cosmetics. Citral extracted from the oil is used in flavouring soft drinks, scenting soaps, and detergents and is widely used in the spa industry. *Cymbopogon citratus* offer an alternative solution for the early cash inflow to the long gestation period in commodity plantation.

MATERIALS AND METHODS

Preparation of Planting Materials

Labisia pumila (clone FaFaF01) were harvested from the germplasm for propagation purposes. The plants were propagated through stem and leaves cuttings in an enclosed mist propagation chamber for 12 weeks. About 600 cuttings were produced. Rooted cuttings were potted in growing media and acclimatized at the greenhouse. *Citrus microcarpa* was propagated through air layering. A combination of top soil and coco peat (ratio 1:1) was used as the rooting media. Rooted stems (66 plantlets) were harvested after 12 weeks and acclimatized at the greenhouse. The planting materials of *C. citratus* were purchased from the commercial nursery in Sungai Buloh, Selangor. All the acclimatized plantlets were transferred to the R&D Centre, FELCRA Nasarudin Belia, Seri Iskandar, Perak for plot establishment.

Establishment of Model Plot

The intercrop planting model was established at the R&D Centre, FELCRA Nasarudin Belia, Seri Iskandar, Perak in November 2019. About 0.08 ha area was planted with 600 *L. pumila* plants, 66 *C. microcarpa* plants, and 180 clumps of *C. citratus* using the intercrop planting model (Figure 1). Data collection on the growth and yield were recorded at the maturity age of each species. The biomass data obtained from this model plot were used for the estimation of yield per hectare.

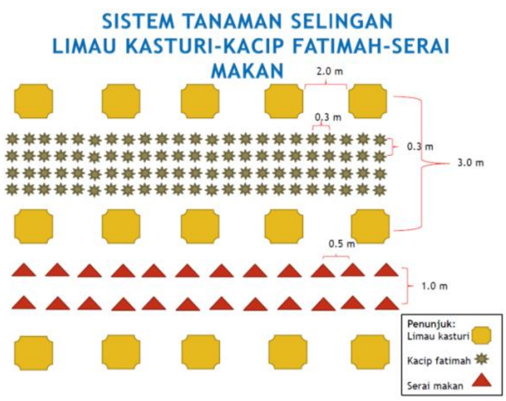

Figure 1 Intercrop planting model of three herbal species

Financial Assessment

A financial assessment has been carried out by the Economic and Analysis Strategic Programme, FRIM to evaluate the viability of this intercrop planting model. The evaluation showed relatively potential financial returns at an interest rate of 65% with a 2.65 benefit cost ratio and a 3-year of payback period.

CONCLUSION

Various efforts have been carried out by the government and NGOs to make Malaysia one of the herbal-producing countries. Cultivation of herbs through intercropping systems is a good initiative in increasing the land productivity of crops. By diversifying several types of crops in one area, farmers can gain benefits in the short, medium and long terms. Besides that, the use of quality cultivars is also important in ensuring optimal and quality yield. This approach can be applied by farmers and villagers to generate additional income through the sales of quality raw materials. This can directly assist the country in ensuring the achievement of a sufficient supply of herbal raw materials for local and external demands.

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LEACHING OF HEAVY METALS: APPLICATION OF BIOSOLIDS AS SOIL CONDITIONER FOR SEEDLINGS GROWTH

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Sewage sludge or biosolids application on soils has been used in agricultural and forest plantations in some countries. However, biosolids are not fully utilised in Malaysia. Biosolids may cause problems on a successive application in heavy metal accumulation in soils, which may lead heavy metals into the food chain via plant uptake. The influence of biosolids on soil properties depends on their amount and characteristics. The origin and treatment method of biosolids production may influence their characteristics. Besides heavy metal content, biosolids may improve soil fertility due to the bioavailability of plant beneficial macro and micro-elements. Therefore, it is crucial to determine the suitable application rate based on soils for agricultural or forest plantation purposes. The rate is based on factors including the concentration of metals, pathogens, toxic compounds, and nutrients. In this study, heavy metal content will be analyzed via leachate samples from seedlings in the nursery. Different types of biosolids were analyzed to identify heavy metal contents that may be harmful to the environment if were to use in the agricultural sector or forest plantation. This pre-assessment on biosolids content through the application on seedlings will be helpful before making any recommendations on using biosolids to the forest plantation in Malaysia.

Keywords: Biosolids, forestry seedlings, heavy metal, soil conditioner

INTRODUCTION

Agricultural application of biosolids is generally considered the best option of management for their organic amendments and plant nutrients (Mingorance et al. 2014). However, depending on their characteristics, they may cause an increase in the heavy metal concentration of treated soils. The influence of biosolid on soil properties depends on the amount and composition of a suitable application concentration of metals, pathogens, toxic organic compounds, and nutrients (Sripanomtanakorn & Polprasert 2002). Some studies showed that biosolids not only improved soil fertility but also enhanced the bioavailability of plant beneficial macro and microelements. Many researchers found that amendment with biosolids may change the soil pH and therefore affect the bioavailability of nutrients (Ngole 2010; Ugbaje & Agbenin 2013).

In general, domestic biosolids have lower heavy metal contents than industrial ones. Origin and treatment method of biosolids may markedly influence their characteristics. The legislation that controls the levels of heavy metal content in biosolids and the maximum concentration in soils is still controversial. In soils, heavy metals may be adsorbed via specific or non-specific adsorption reactions. In solution, heavy metals can be present either as free ions or complexed with organic and inorganic ligands. The objective of this study was to evaluate the cumulative amount of heavy metals (As, Cd, Cr, Pb) leached from polybags after 10 and 30 days of planting seedlings in the nursery. This probing study may improve understanding of using biosolids for planting and to evaluate the significance and implications of emerging biosolids before entering the market.

MATERIALS AND METHODS

Site Selection

The nursery of Forest Research Institute of Malaysia was selected for this study. One year old of *Hopea odorata* (merawan siput jantan) seedlings were planted in polybags by mixing sewage sludge-based compost, topsoil, and sand in different ratios and to evaluate the potential use of these substrates as growing media for commercial production of forestry seedlings. Sewage sludge is a reliable source of nitrogen and phosphorous for plants. Nitrogen is an essential nutrient for plant growth since it is a constituent of all proteins and nucleic acids.

Sludge Collection

Sludges were collected from industrial and residential sites in Gombak, Selangor and dried properly. The dried sludges were also sieved to separate them from other foreign materials. Then the sludges were mixed thoroughly at different ratios as below:

Group	Treatment	Ratio
M3	Top soil : compost+microbes : sand	3 : 2 : 1
M4	Top soil : biosolids 267 : sand	3 : 2 : 1
M5	Top soil : biosolids 259 : sand	3 : 2 : 1
M6	Top soil : biosolids 267 : sand	3 : 1 : 1
M7	Top soil : biosolids 259 : sand	3 : 1 : 1
M8	Top soil : biosolids 267 : sand	0 : 2 : 1
M9	Top soil : biosolids 259 : sand	0 : 2 : 1
M11	Top soil : biosolids 259 : sand	0 : 1 : 1

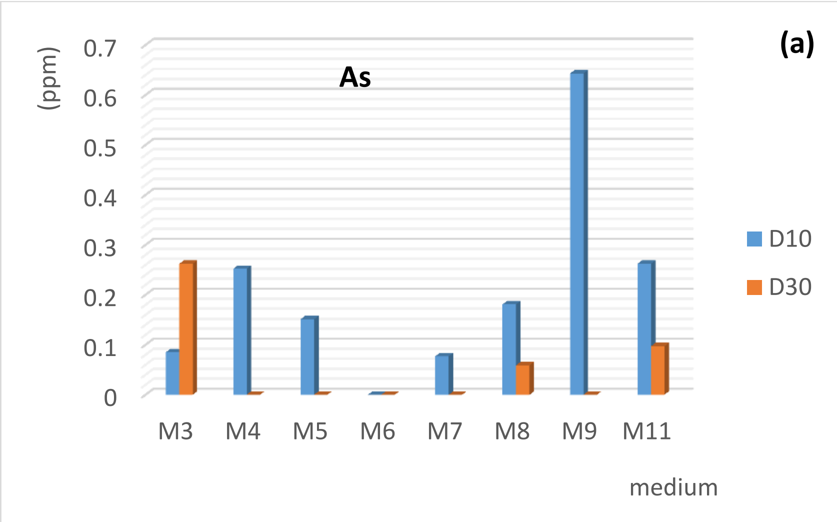
Polybags with 6×9 inches were used for the experiment. A Completely Randomized Design (CRD) was used for a total of eight treatments including a control and four replications for each treatment with five polybags for each replication.

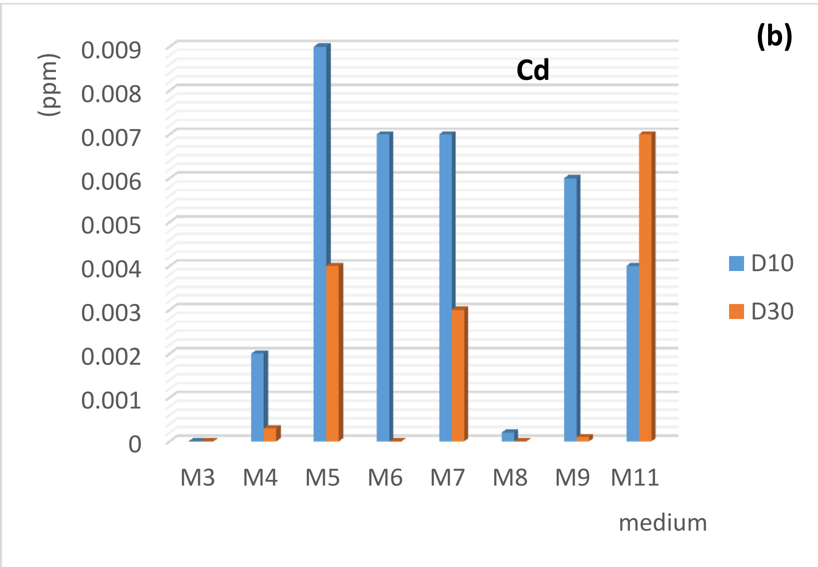
Collection of Leachate and Chemical Analysis

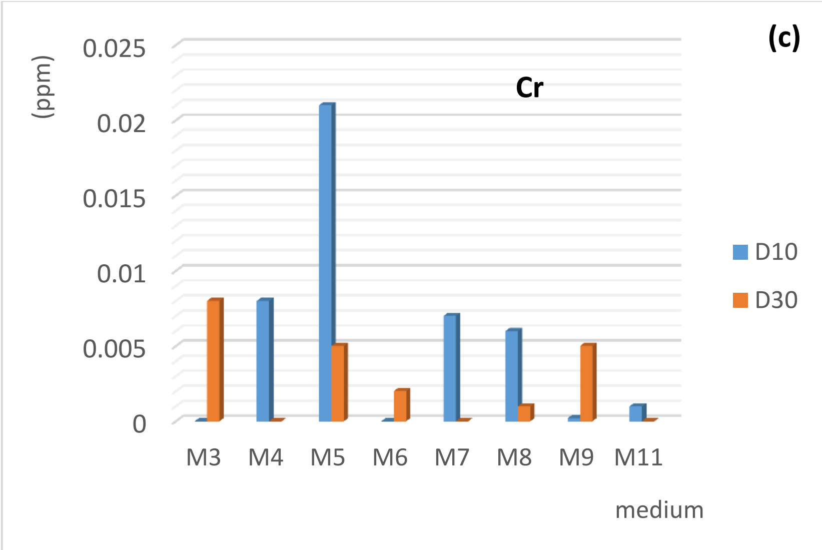
The seedlings were watered daily with the same amount of water. After 10 and 30 days of planting, the leachate was collected using a container and transferred into a screw cap bottle for further analysis. The leachate samples were analyzed for arsenic, cadmium, chromium, and lead. The analyses were performed by the Soil Chemistry Laboratory, FRIM using the ICP method.

RESULTS AND DISCUSSION

The cumulative amount of As, Cd, Cr, and Pb leached after 10 and 30 days were very low, and some elements could not be detected. There was no significant pattern between the amount of heavy metal elements tested and the medium with the time of planting (Figure 1 a, b, c, and d).







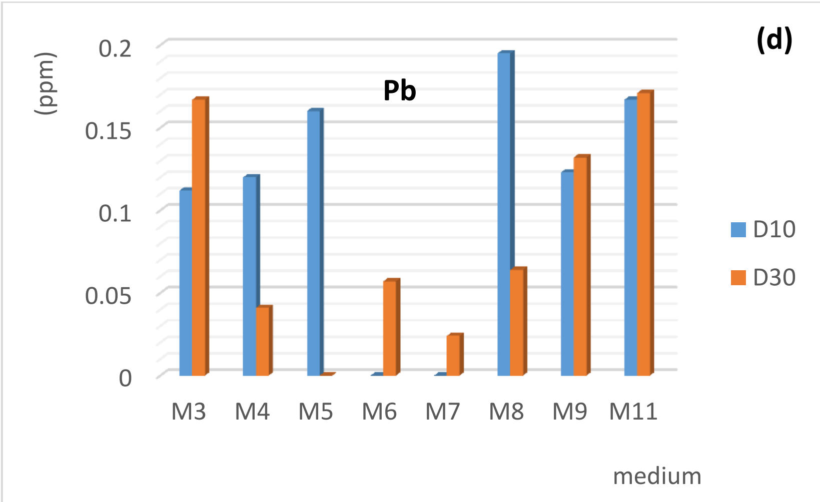


Figure 1 The amount of As, Cd, Cr, and Pb (a, b, c, d respectively) leached after 10 and 30 days in different media

However, most of the elements were detected after 10 days of planting. The observation was made on seedlings' growth and showed no effect of biosolids could be harmful to the seedlings. Most of the nursery seedlings respond positively to sludge fertilization. Lead elements are still detected after 30 days of planting in most of the medium. It shows that this element may take a longer time to leach from the medium.

The sludges collected from residential areas were treated and known as biosolids. Most of the elements contained in the treated sludges/biosolids were washed off during the treatment. Sludges from residential areas contain lower amounts of heavy metals as compared to sludges from industrial areas. Therefore, this may cause lower amounts of heavy metal elements detected in our samples. Besides that, plants can reduce heavy metals from the sludge-amended soil because these heavy metals are the micronutrients. These micronutrients are required in small quantities for plant growth and development (Iqbal et al. 2007). As suggested by Lokman et al. (2013), biosolids are suitable to be used in forested sites due to enrichment of the soil at a lower cost. Though biosolids contain a range of potentially toxic metals, application on forest land and nurseries has become a potential method for the disposal and biological recycling of sludges because the forest is a non-food chain (Korentajer 1991). Besides, studies showed that the health risk presented by vegetables grown on sewage sludge-amended soils was low because of the high rates of evaporation in environments and the sterilising effect of the sun (Ngole 2007).

Certainly, considering the large amount of biosolids produced and suggested reuse on land, it is important for continuous monitoring and data collection in order to evaluate the significance and implications of emerging biosolids in the market.

CONCLUSION

In conclusion, the application of biosolids in non-food chain plants like in nursery soil to raise quality seedlings will become one of the alternative methods for environmentally safe disposal of biosolids. However, it is necessary to find out the accurate rates of sludge application in order to avoid, over or under fertilization.

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EVALUATION OF CONTAINER TYPE AND POTTING MEDIUM FOR RAISING QUALITY OF *HOPEA ODORATA* (DIPTEROCARPACEAE) IN THE NURSERY

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Successful afforestation programmes demand the use of high-quality seedlings. Thus, to achieve this goal, the present study was conducted to evaluate the effect of container type and potting media on the growth performance of *Hopea odorata* seedlings for 12 months. The experiment was laid out in a factorial completely randomized design with 8 treatment combinations, replicated thrice. The treatment consists of four potting media filled with a mixture of soil, compost, cocopeat, and sand at a ratio of, viz., 3:1:1:1 (M1), 1:1:1:1 (M2), 1:1:3:0 (M3) and 1:2:2:0 (M4), respectively and two container types: polybag 15 x 20 cm (B1) and root trainer RB 600 tube (B2). At the end of 12 months, three seedlings were selected randomly for measurement of growth and development parameters such as the number of leaves, plant height, and total seedling fresh weight. The results of the present study show that the interaction of container type and potting media had a significant effect ($P \leq 0.05$) on all the growth parameters in terms of height, number of leaves, and total seedling fresh weight of *H. odorata* seedlings. The findings suggest that a root trainer filled with potting media consisting of soil, compost, cocopeat, and sand in the ratio of 1:1:3:0 (M3) was found to be the most suitable in terms of overall growth and root development of good quality *H. odorata* seedlings raised under nursery conditions in order to boost large scale seedling production of *H. odorata* for afforestation programmes.

Keywords: Merawan siput jantan, root trainers, poly bags, potting media, growth

INTRODUCTION

In recent years, dipterocarp species have received a lot of attention as they are suitable species for reforestation and forest planting programs in degraded forests in Malaysia (Aminah et al. 2004; Ang et al. 2017; Husin et al. 2020). Thus, nursery seedling production is essential to meet the demand for high-quality Dipterocarpaceae planting stock on time to ensure better establishment and survival rates after field planting in degraded forest areas (Zaidey et al. 2010). *Hopea odorata* is a dipterocarp rainforest tree that is locally known as “merawan siput jantan” or “cengal pasir” and is commonly found in Southeast Asia for instance, Thailand, Peninsular Malaysia, Myanmar, and Indo-China (Cochard et al. 2021; Zahidah et al. 2021). Besides, they are a dominant species in river riparian areas and moist forests in Southern Vietnam (Asanok et al. 2020). This species is currently in high demand for forest plantations due to its amazing growth, unique characteristics such as hardness, durability, and water resistance, and promising financial returns (Zahidah et al. 2021).

However, the exploitation of them in the timber industry and the clearance of forest habitats for agriculture and urbanisation have resulted in a drop in natural ecosystems, hence they are classified as vulnerable species in the International Union for Conservation of Nature (IUCN) Red List of Threatened Species (Ly et al. 2017; Asanok et al. 2020).

Potting media is an important ingredient as it provides nutrients and water while also supporting the growth and quality of containerized seedlings in nurseries (Chu et al. 2020). The different proportions of potting substrates affect the texture and structure of the potting mixture which controls the water holding capacity, aeration, and nutrient availability (Easton 2021). Therefore, a fertile and optimal ratio of potting medium is needed to hasten the growth and development of forest seedlings in nursery conditions. Besides, the container type is also crucial in manipulating the growth, development, and flowering of containerized seedlings as it would affect the rooting volume (Deogade et al. 2020). Forest seedlings are commonly cultivated in polythene bags of different sizes with standard John Innes potting material in a 3:2:1 ratio for massive scale seedling production of forest plantation species (Aminah et al. 2004; Annapurna et al. 2004). However, this conventional practice leads to certain problems such as bulk, nutrient deficiency, poor drainage and aeration, and root coiling, as well as transportation and distribution difficulties (Annapurna et al. 2004; Cedamon et al. 2005; Nabayi et al. 2018). As a result, seedling mortality is high in the field.

These issues can be minimised by introducing root trainers as containers. In recent years, root trainer technology has been gaining momentum due to its ability to improve polybag planting systems. It is a tool used in nurseries to aid with seedling cultivation. Besides, it is containerized seedling technology that is lightweight, eco-friendly, reusable, and easy to carry for transplant, transportation, and distribution, which saves time and money for the rubber planter (Wang et al. 2020). Despite having a higher initial cost than polybags, modern containers can be reused for five to twelve years, depending on the container material and the number of nursery production cycles (Haase et al. 2021). Root trainers do not require medium changes, provide less risk of transplant shock, and prevent roots from coiling up due to the vertical ribs inside the root trainer having the characteristic of the antispiral design, and require a small space making them ideal for mass seedling production (Nayagam & Varghase 2015). Rather than the conventional polybag planting method, root trainers are gaining popularity as a way to prevent deformation and root spiralling while also improving wind tolerance in the field (Wang et al. 2020). Hence, future plantation programmes may be more effective through the use of root trainer technology in nurseries (Nayagam & Varghase 2015). However, there was a dearth of crucial information on the effect of raising dipterocarp seedlings in root trainers with proper potting media to enhance physical and root growth in seedlings at nursery stages. This is because root trainer technology is dependent upon a suitable potting medium for raising forest species under root trainer seedlings. Therefore, the objective of this study is to evaluate the effect of container type and potting media on the growth performance of *H. odorata* seedlings for 12 months in order to determine the most suitable container and optimum potting media for raising optimum quality seedlings of *H. odorata* under nursery conditions.

MATERIALS AND METHODS

Experimental Site

This experiment was conducted in July 2019 at the Main Nursery of Forest Research Institute Malaysia (FRIM). The average annual rainfall is 2,579 mm with a mean monthly temperature of 25.9˚C, whereas the mean relative humidity ranges between 81.29% and 89% (en.climate-data.org).

Experiment Layout

The experiment was conducted in a nursery using two container types: polybag 6 x 8 inch (B1) and root trainer RB 600 tube (B2) and four potting media consisting of topsoil, compost, cocopeat, and sand in a ratio of 3:1:1:1 (M1), 1:1:1:1 (M2), 1:1:3:0 (M3) and 1:2:2:0 (M4), respectively. There were 8 treatment combinations in a factorial completely randomised design (CRD). Each treatment was replicated thrice.

Methodology

The wildings of *H. odorata* were collected from FRIM's main campus. The topsoil, compost, coco peat, and river sand were sieved well (5 mm sieve) to eliminate debris before thoroughly mixing the potting media for respective treatments. Next, the polybag and root trainer were filled with the potting media of M1, M2, M3, and M4, respectively. Prior to the experiment, wildings of *H. odorata* were applied with those treatments. The experiment was carried out in a netted rain shelter with auto sprinkle irrigation. Throughout the experiment, seedlings were regularly checked for possible pests and diseases.

Potting Media Analysis

Prior to the experiment, the chemical properties of the potting media, *viz*. their pH, N, P, K, Ca, Mg and Na) of 4 ratios of potting media were tested according to the standard procedure of soil chemical analysis (Malaysia Standard 1980).

Measurement of Growth Parameters of *Hopea odorata* Seedlings

At the age of 12 months, a random sample of three seedlings from each treatment was selected and uprooted to record the selected growth parameters. The seedlings were measured, counted, and weighed to determine their height, number of leaves, and total seedling fresh weight.

Statistical Analysis

SPSS software version 26 (SPSS Inc, USA) was used to perform statistical analysis on all data. Analysis of variance (ANOVA) was used to analyse the data, and means were compared using Duncan's multiple range Post Hoc test, with the significance of results tested at P 0.05 to evaluate significant differences.

RESULTS AND DISCUSSION

Chemical Properties of Potting Media

Table 1 represents the chemical properties of the four potting media used in this study. The pH of the potting media ranged between 6.96 and 7.84 which were within the standard range of most plants that have optimum nutrient availability (Nabayi et al. 2016). The potting media of M4 has the highest pH due to relatively higher macronutrient contents (N, P, and K) and micronutrient contents (Ca, Mg, and Na) as compared to other potting media. Besides, this was due to higher compost composition, which results in quick proton (H^+) ion exchange between compost and soil, resulting in an increase in pH (Wong et al. 1998; Tang et al. 1999; Ch'ng et al. 2014). On the other hand, M1 shows poor fertility status as it results in the lowest available P, exchangeable K, and Ca compared to other potting media due to a lack of organic materials, which in turn will result in poor growth of seedlings in M1.

Table 1 Chemical properties of four potting medium

Properties	Potting media			
	M1	M2	M3	M4
pH (%)	7.02	7.26	6.96	7.84
Total N (%)	0.19	0.18	0.21	0.39
Total C (%)	2.43	2.28	2.66	5.89
Available P (ppm)	42.28	43.93	48.50	65.63
Exchangeable K (cmol/kg)	1.95	2.01	2.60	7.36
Exchangeable Ca (cmol/kg)	3.91	3.98	3.94	8.08
Exchangeable Mg (cmol/kg)	0.94	0.89	0.96	3.54
Exchangeable Na (cmol/kg)	0.06	0.03	0.13	0.82

Note: N: nitrogen; C: carbon; P: phosphorus; K: potassium; Ca: calcium: Mg: magnesium: Na: sodium. M1: potting mixture at ratio of 3:1:1:1; M2: potting mixture at ratio of 1:1:1:1; M3: potting mixture at ratio of 1:1:3:0 and M4: potting mixture at ratio of 1:2:2:0.

Effect of Container Type and Potting Media on the Growth and Root Pattern of *Hopea odorata* Seedlings

One-way ANOVA indicated tha the effect of container type and potting media ratio on the physical growth performance of *H. odorata* seedlings (Table 2). *H. odorata* raised in the B2M3 treatment combination had a significantly higher number of leaves (40) at the end of the experiment compared to other treatments. Additionally, the plant height of *H. odorata* seedlings was also significantly higher in B2M3 followed by B2M2 and B2M4 with values of 45.85 cm, 43.65 cm, and 43.58 cm, respectively, at the end of the experiment. The total fresh weight of *H. odorata* seedlings was significantly higher in B2M3 followed by B2M2, B2M4, and B1M2 with values of 81.67 g, 78.33 g, 76.67 g, and 65 g, respectively. Besides, the root pattern of seedlings raised in B2M3 was an uncoiled tap root system with multiple lateral roots (Figure 1). This was due to root trainers providing favourable conditions for promoting the good development of the seedlings root systems. Hence, seedlings raised in root trainer encourage root development to go downward to the drainage hole, where they will cease growing due to air pruning and the low humidity impact, which is effective when roots are lifted above the soil surface with stand (Aminah et al. 2004; Nayagam & Varghase 2015). Meanwhile, M3 potting media provides nutrient-rich potting media that also has good water holding capacity and adequate aeration and drainage as well as providing ideal space for the root system (Mohanan & Sharma 2005; Gupta et al. 2018; Deogade et al. 2020). Furthermore, Kouakou et al. (2021) state that cocopeat is a well-drained substrate with adequate water-holding capacity, better nutrient retention capacity, and good aeration thus boosting the development of the root system of plants. Besides, according to Islam et al. (2019), when seedlings are raised in good media, they have a greater chance of establishing and growing in the main field. Therefore, the treatment combination of B2M3 demonstrated the most effective and best result in the physical growth performance of *H. odorata* seedlings at the nursery stage as the results showed an increase in physical plant morphology and rapid root growth.

On the other hand, due to lack of proper aeration and the poor water holding capacity of the potting media, the seedling produced in the B1 container with improper potting media (M1) exhibits significantly lower growth performance in terms of height and number of leaves, lack of total seedling fresh weight, and stunted root growth pattern (Table 2 and Figure 1). This was due to the flat bottom and smooth walls of the polythene container. The root system of seedlings grown in polybags tends to spiral pattern and develop laterally around the container's side, thereby affecting growth in the nursery and after transplanting in the planting sites (Mohanan & Sharma 2005).

Table 2 Effect of container type and potting media on the growth of *Hopea odorata* seedling after 12 months at nursery conditions

Parameter	Number of leaves	Height (cm)	Total fresh weight (g)
Treatment			
B1M1	27^{e}	10.46^{d}	$35b^{c}$
B1M2	39^{ab}	38.38^{b}	65^{a}
B1M3	34^{cd}	35^{c}	33.33^{c}
B1M4	36^{bc}	$36b^{c}$	63.33^{ab}
B2M1	32^{d}	34.66^{c}	61.67^{bc}
B2M2	39^{ab}	43.65^{a}	78.33^{a}
B2M3	40^{a}	45.85^{a}	81.67^{a}
B2M4	32^{d}	43.58^{a}	76.67^{a}

Different letters in a column indicate significant differences according to Duncan's multiple range tests at $P \leq 0.05$. B1: polybag; B2: root trainer; M1: potting mixture ratio of 3:1:1:1; M2: potting mixture ratio of 1:1:1:1; M3: potting mixture ratio of 1:1:3:0 and M4: potting mixture ratio of 1:2:2:0.

Figure 1 The root pattern of *Hopea odorata* seedlings raised in polybag filled with M1 potting media (left) and in root trainer (B2) filled with M3 potting media (right) after 12 months at nursery conditions

CONCLUSION

After 12 months, overall growth and root development of *H. odorata* seedlings in the nursery were significantly higher when raised in root trainers filled with potting media containing a 1:1:3:0 ratio of topsoil, compost, cocopeat, and sand due to improvement in the plant's nutrient uptake. This combination provided favourable conditions for promoting good development of the seedlings root systems. Hence, this treatment combination was found suitable for raising optimum growth and quality *H. odorata* seedlings in the nursery conditions for afforestation programs which is a lightweight container with an optimum potting media that is easy to transport and transplant, especially to difficult-to-reach sites.

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EFFECTIVENESS OF COVER CROPS FOR RESTORATION ACTIVITY IN HIGHLAND

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Cover crops (CC) are well-known as a long-term crop management method for improving biodiversity and fertility in degraded agricultural soils by reducing soil and water loss, replacing organic matter, and reducing soil and water loss. The main issues in highland areas are caused by the increase in population density and land degradation. The protective canopy of a cover crop reduces the impact of raindrops on the soil surface, slowing the dissolution of soil aggregates. Soil erosion and runoff are reduced significantly, while infiltration is significantly increased. Initially, the use of CC in degraded highland areas was difficult as the soil in the area was very nutrient-deficient even to support the growth of seedlings. The seeds of *Mucuna bracteata* were sown in a planting hole with several treatments. Almost 90% of seeds germinated from all treatments. However, seeds sown in holes with the original soil and gel pre-soaked with liquid soil fertiliser show better growth performance of *M. bracteata* seedlings. The time taken for *M. bracteata* to cover the surrounding area was relatively long due to the very poor conditions of the soil. A cover crop regimen will enhance soil organic matter over time, resulting in improved soil structure and stability, as well as greater moisture and nutrient-holding capacity for plant growth. Through enhanced infiltration, these properties will reduce runoff problems in highland areas.

Keywords: Cover crop; highland; forest restoration; *Mucuna bracteata*; degradation

INTRODUCTION

A degraded forest has undergone a degradation process that harmed its structural and functional qualities. Human activities cause forest degradation, which is influenced by macroeconomic, demographic, technological, institutional, and political variables. Degraded forests in the majority of situations, can lead to changes in soil and water, as well as the interactions between these components, impacting forest function and reducing ecosystem goods and services. As a result, forest degradation is now widely recognised as a severe environmental, social, and economic issue around the world.

In Malaysia, most of the area was cleared for agriculture and housing estate. The consequences of these activities had increased losses of nutrients and soil; downstream impacts, such as reductions in water quality due to increased sedimentation and changes in water yield; and widespread reductions in biodiversity and the supply of various ecological goods and services. Total nitrogen level decreases as soil organic matter decrease, resulting in increased compaction, hardening, crusting, and susceptibility.

Prior to replanting, the soil structure needs to be restored by using several methods such as physic-mechanical, chemical, or vegetative approaches. One of the simplest and cheapest methods is by using the vegetative approach. This method controls runoff and erosion using cover crop planting. Cover crops (mostly legumes) help in reducing nutrient losses due to leaching and improving soil structure, resulting in enhanced aeration, infiltration, and moisture retention (Halus et al. 2016). A plant species such as *Mucuna bracteata* is often used to cover exposed land areas and increase soil fertility. The growth of *M. bracteata* is very fast as it only takes three to six months to adapt to the environment and help fertilise and hold the soil structure.

The study of using *M. bracteata* in degraded forest/land is still limited. A study needs to be pursued to measure the effectiveness of *M. bracteata* in improving the soil physical properties and reducing the runoff and erosion in degraded forests/land. Therefore, this study focuses on the survival and growth performance of *M. bracteata* in the degraded forest which is composed of sandy lateritic soil lacking nutrients.

MATERIALS AND METHODS

The experiments were conducted at Forest Reserve Bukit Jerut 1, Tringkap, Cameron Highland, Pahang. The altitude of this area is ± 1500 meters above sea level with temperatures ranging from 17-25°C. The average amount of annual precipitation is 999.9 mm. Soils at experimental sites are sandy lateritic soil lacking nutrients. *Mucuna bracteata* was selected for this study based on their growth potential and suitability for soil fertility improvement.

Mucuna bracteata was sown in 15 cm (depth) x 30.5 cm (diameter) of the planting hole (Figure 1). Three seeds were sown per planting hole. The space between planting holes was set at 30.5 cm. The treatments (i) no soil amendment (control) – T1 (ii) original soil + gel (pre-soaked with liquid soil fertiliser) – T2 (iii) coconut husk + gel (pre-soaked with liquid soil fertiliser) – T3, and (iv) coconut husk – T4. The experiment was arranged in a randomised complete block design with three replications per site.

RESULTS AND DISCUSSION

In humid tropics, runoff and erosion are the primary causes of soil degradation, resulting in the transfer of organic matter and nutrient-rich surface soil layers. It affects soil fertility and causes productivity to decline. As a result, efforts to limit runoff and erosion are required via physic-mechanical, chemical, and vegetative approaches. The vegetative approaches are frequently preferred as they can reduce runoff and erosion and increase soil fertility. The study on the effectiveness of *M. bracteata* in improving soil physical properties and reducing runoff and erosion in degraded areas is still limited. However, previous studies conducted on oil palm plantations showed that *M. bracteata* litter acted as organic mulch to minimise runoff and erosion (Hasnol et al.

2012). *M. bracteata* is a leguminous plant widely found in Malaysia and is a popular cover crop in oil palm plantations. The plant is known to proliferate quickly at a rate of about 10–15 cm/day and shows the ability to grow in different types of soil (Tang & Law 2019).

This study aimed to expand the areas covered by *M. bracteata* to immediately reduce water runoff/landslides. It was found that *M. bracteata* were able to germinate using different methods of seeds sowing in highlands at an altitude ± 1500 m above sea level with temperatures ranging from 17-25°C. The germination percentage of the seeds was about 70 to 90% (unpublished data). However, the growth performances of *M. bracteata* seedlings were slow and the time taken to cover the surrounding area was relatively long. The seedlings were assisted with liquid fertiliser to speed up their growth. After nine months of cultivation, planted *M. bracteata* managed to cover most of the degraded area in the plot (Table 1, Figure 2). Figure 3 shows *M. bracteata* seeds sow in the original soil; pre-soaked gel with liquid soil fertiliser produced a high germination rate and coverage of the degraded land. The usage of gel in the degraded land area helps in retaining the moisture for the plantlet to grow. This area is far from a water source and will cause high mortality to most of the plantlets planted in this area. As shown in the result (table 1), the ground coverage of the *M. bracteata* seed using T4 and T1 was not detected could be due to mortality as this treatment does not include material that can retain moisture although there is a compost material in the treatment; suggested that moisture is crucial in this highland degraded area.

Figure 1 Study plots in degraded forestland, which composed of sandy lateritic soil lacking nutrients

Table 1 Ground coverage (%) of *Mucuna bracteata* in Bukit Jerut, Cameron Highland

Treatments	Months after planting			
	3	6	9	12
T1	0	0	NA	NA
T2	0	30	50	75
T3	0	20	50	60
T4	0	10	NA	NA

Figure 2 (a) Ground covers after 6 months, (b) and (c) Ground covers after 9 months using T2

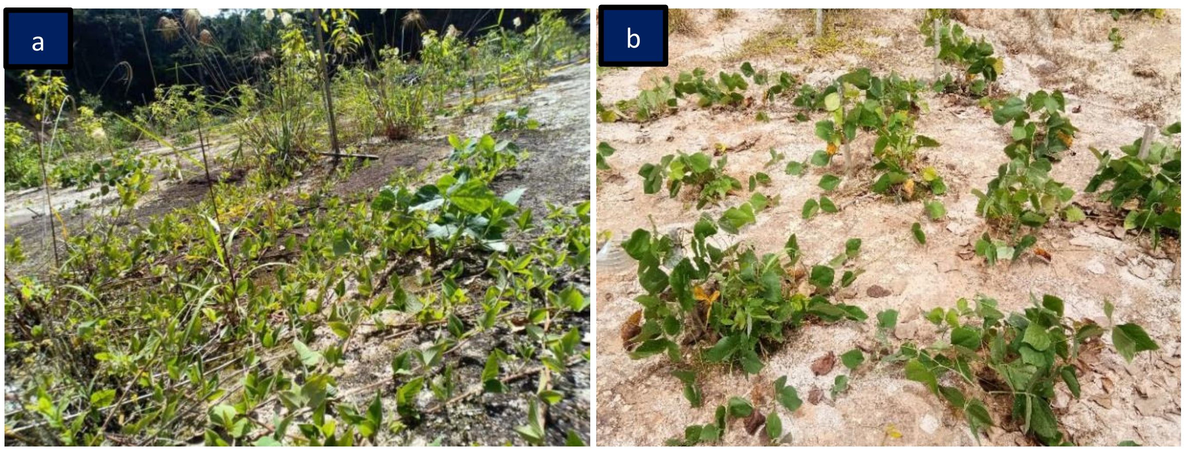

Figure 3 (a) and (b) ground cover after 12 months using T2

CONCLUSION

The study indicates that *M. bracteata* can survive in highland degraded areas. However, the use of growth promoters was needed to assist the growth in poor soil. *M. bracteata* seeds sown with treatment T2 and T3 show high germination percentage and ground cover up to 75% after 12 months of planting. The use of fertiliser also affects the growth and coverage of *M. bracteata* in this study area. Broader coverage of *M. bracteata* planting perhaps will reduce the runoff, increase the infiltration, and prevent soil erosion. Future studies will require a much longer observation to determine the effectiveness of planting *M. bracteata* as a cover crop in degraded forestland in highland areas. The short monitoring period covered by this study was not sufficient to provide a strong foundation for decision-making. Forthcoming studies can include understanding the processes involved in rehabilitating a degraded highland area in terms of density and the rooting system of *M. bracteata*.

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RESTORATION OF DEGRADED LAND IN JANDA BAIK AND CAMERON HIGHLANDS USING MULTIPURPOSE PIONEER SPECIES *MACARANGA TANARIUS*

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The federal government funded the restoration, reclamation, and rehabilitation of degraded areas (3RSM) programme which is managed by the Forestry Department Peninsular Malaysia (JPSM). The programme includes a study on mahang (*Macaranga tanarius*) as a pilot species in a landslide restoration project in Cameron Highlands that involved degraded sites in Jerut 4, Jerut 1, and Terla. *M. tanarius* was chosen as a pilot plant due to the availability of seeds throughout the year, a high percentage of seed germination, and readily available seedlings. Furthermore, *M. tanarius* grows naturally at an altitude of 1000 m above sea level in Cameron Highlands. Its high-altitude tolerance is expected to contribute to the suitability of *M. tanarius* as nurse trees for seedlings of quality forest species planted at the Bukit Jerut and Kuala Terla project sites, located at an altitude of around 1600–1800 m above sea level. Based on the growth performance analysis, the average height of the seedlings increased gradually, while the survival rate declined drastically. In Jerut 4 (1,680 m asl), the average height at five months (after planting) was recorded at 42.7 cm, 48.9 cm at seven months, and 56.8 cm at 12 months. The difference in average height at 12 months and five months is 14.1 cm. In Jerut 1 (1,540 m asl), the average height at five months (after planting) was recorded at 27.3 cm, 33.6 cm at seven months, and 32.6 cm at 12 months. The difference in average height at 12 months and five months is 5.3 cm. The survival rate of *M. tanarius* seedlings in Jerut 4 and Jerut 1, 12 months after planting, was poor at 22%. The five-month survival rates in Jerut 4 and Jerut 1 were 84.8% and 61.1%, respectively. The rate dropped during the seventh month, with Jerut 4 and Jerut 1 recorded 75.2% and 43.7% survival rates, respectively. In Terla (1,004 m asl), the average height five months after planting was 19.4 cm, with a 74.5% survival rate. However, as the site had to be abandoned, no further measurement was taken. The *M. tanarius* was well adapted and performed well in its growth; however, variation exists in height and survival. Based on the results of this study, *M. tanarius* is a promising pioneer species for restoration, especially as the nurse tree for the planting of quality timber trees.

Keywords: Restoration, highland, rehabilitation

INTRODUCTION

Pioneer species play a vital role in the restoration of deforested lands. Pioneer species usually have good growth characteristics, are readily available, free from pests and diseases, have conservation value, and adapt well to problematic areas (Whitmore 1975; 1978). Mahang (*Macaranga tanarius*) is a pioneer species that grows widely in disturbed areas in Malaysia, with 27 species (Whitmore 1967; 2008).

The federal government has funded the restoration, reclamation, and rehabilitation of degraded areas (3RSM) programme which is managed by the Forestry Department Peninsular Malaysia (JPSM). The programme includes a study on *M. tanarius* as a pilot species in a landslide restoration project in Cameron Highlands. *M. tanarius* was chosen as a pilot plant due to the availability of seeds throughout the year, a high percentage of seed germination, and readily available seedlings (Rosdi 2019). Furthermore, *M. tanarius* grows naturally at an altitude of 1000 m above sea level in Cameron Highlands. Its high-altitude tolerance is expected to contribute to the suitability of *M. tanarius* as nurse trees for seedlings of quality forest species planted at the Bukit Jerut and Kuala Terla project sites, located at an altitude of around 1600–1800 m above sea level.

MATERIALS AND METHODS

The restoration project involved two areas, i.e., Cameron Highlands and Janda Baik. In Cameron Highlands, the project involved degraded sites in Jerut 4, Jerut 1, and Terla. A total of 4,500 *M. tanarius* wild seedlings were collected and planted in the FRIM nursery. Three thousand two hundred wild seedlings were transferred to the temporary nursery at the Cameron Highlands Forestry Office. FRIM reserved the remaining 1,300 seedlings for Janda Baik.

Due to improper water supply and insufficient watering facilities provided at the temporary nursery in Cameron Highlands, high mortality of seedlings (46.13%) occurred. The remaining 1,724 seedlings survived and were planted in Jerut 4, Jerut 1, and Terla. Planting activity was started in July 2019, and 50 g of Christmas Island rock phosphate (CIRP) was applied to each seedling. Data on seedlings' height were taken in December 2019, February 2020, and July 2020.

RESULTS AND DISCUSSION

Based on the growth performance analysis, the average height of the seedlings increased gradually, while the survival rate declined drastically (Table 1 and Figure 1). In Jerut 4 (1,680 m asl), the average height at five months (after planting) was recorded at 42.7 cm, 48.9 cm at seven months, and 56.8 cm at 12 months. The difference in average height at 12 months and five months is 14.1 cm. In Jerut 1 (1,540 m asl), the average height at five months (after planting) was recorded at 27.3 cm, 33.6 cm at seven months, and 32.6 cm at 12 months. The difference in average height at 12 months and five months is 5.3 cm.

The five-month survival rates in Jerut 4 and Jerut 1 were 84.8% and 61.1%, respectively. The survival rates dropped to 75.2% and 43.7% in Jerut 4 and Jerut 1 at seven months, respectively. The survival rate of *M. tanarius* seedlings in Jerut 4 and Jerut 1 has dropped drastically to 22 % 12 months after planting. Replacement of seedlings was conducted in October 2020 in Jerut 4 and Jerut 1. However, due to the COVID-19 MCO, the growth assessment has been postponed. In Terla (1,004 m asl), the average height at five months after planting was 19.4 cm, with 74.5% survival rate. However, as the site had to be abandoned, no further measurement was taken.

Table 1 Average height and survival rate of *Macaranga tanarius* seedlings

Sites	Elevation (m)	Average Height (cm)	Survival Rate (%)	Average Height (cm)	Survival Rate (%)	Average Height (cm)	Survival Rate (%)
		5 months		7 months		12 months	
Jerut 4	1,680	42.7	84.8	48.9	75.2	56.8	22.0
Jerut 1	1,540	27.3	61.1	33.6	43.7	32.6	22.0
Terla	1,004	19.4	74.5	-	-	-	-

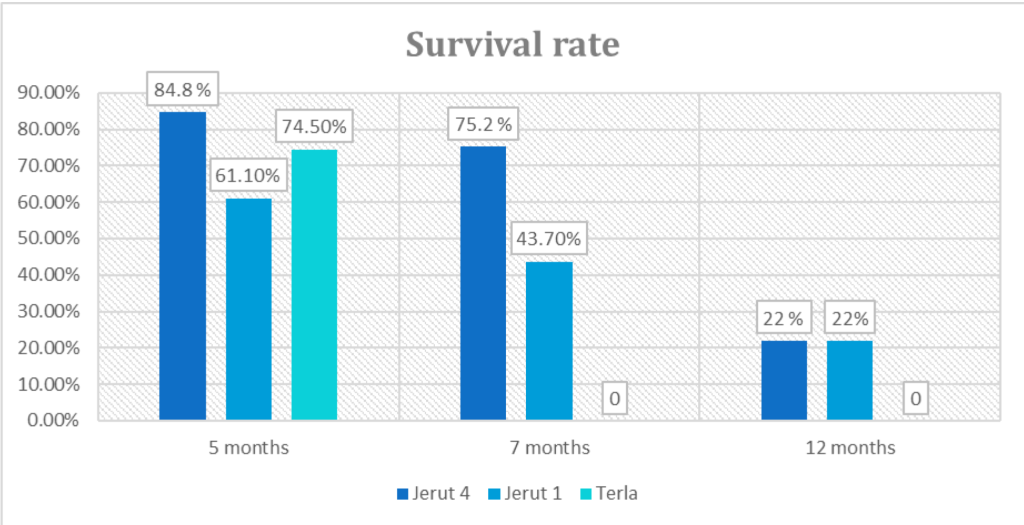

Figure 1 Survival rate of *Macaranga tanarius* seedlings during 5, 7, and 12 months at Jerut 4, Jerut 1, and Terla, Cameron Highland, Pahang

Growth observation at Terla had to be abandoned due to a high mortality rate (around 99%). The planted seedlings were cleared and damaged during the weeding activity conducted by the forestry department. Previously, no weeding activities were conducted at the Terla site upon replanting of dipterocarp seedlings. Overgrown weeds and lianas eventually slowed down the growth of the dipterocarp seedlings. The restoration project in Janda Baik was later postponed to 2021 as no allocation was available for a research plot and the unavailability of a restoration project to be conducted at that moment.

There were some limitations while conducting the study and listed as follows:

1. MCO restriction caused a delay in fieldwork activities, maintenance work, inspection, and inventory assessment.
2. High seedlings mortality rate as 1, 476 seedlings transferred to a temporary nursery in Cameron Highlands wilted and died due to insufficient water supply. The nursery was also severely damaged by fallen trees and branches. Seedlings were left unshaded by the fallen trees and exposed to extreme weather (Figures 2 & 3).

Figure 2 Nursery structures damaged by fallen trees and branches

Figure 3 Fallen trees damaged and exposed unshaded seedlings to hot weather

3. The monitoring activities at Terla were abandoned due to a high mortality rate as all planted seedlings were damaged during the weeding activity. Overgrown weeds and lianas prevented the growth of dipterocarp seedlings planted earlier by JPSM.
4. The restoration project in Janda Baik has to be postponed to 2021 as there was no allocation for a research plot for a restoration project.

CONCLUSION

Overall, the initial objectives of the restoration of degraded land in Cameron Highlands and Janda Baik through planting a multipurpose pioneer species mahang (*M. tanarius*) were partially delivered. Overall, the seedlings planted in Jerut 4 showed a higher average height compared to Jerut 1. However, the growth performance could not be compared to Terla, since the seedlings mortality rate was relatively high and data from Terla had to be excluded.

The selection of bigger and older wild *M. tanarius* seedlings than the dipterocarp seedlings would have helped achieve the study objective ofproviding sufficient shade. Additionally, the duration of the study needs to be extended in order to achieve better outcomes and more reliable and accurate growth data.

The alterations and modifications of the project approaches are required to overcome a few project limitations. The study, however, has managed to provide some insight and contributed to the restoration of degraded forests.

ACKNOWLEDGEMENT

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EFFECTS OF MICROCLIMATE ON TREE GROWTH AND PHYSIOLOGY AT LENTANG FOREST RESERVE, PAHANG

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Restoration of degraded forests is crucial not only for the recovery of forest structure but also the ecological functions. Species selection and planting techniques are thus important to ensure the success of rehabilitation programmes. Lentang Forest Reserve in the state of Pahang has been restored with several indigenous timber species and one of these was *Shorea leprosula*. The effects of microclimate on the growth and physiology of *S. leprosula* as a result of planting in shade and gap areas were studied. Results showed that the area in the gap had higher variations in terms of air temperature and relative humidity. Trees planted in the gap area recorded better height and diameter growth. In addition, trees in gap had a higher maximum net photosynthetic rate of 13.50±0.88 µmol $m^{-2}s^{-1}$ compared to trees under shade with only 10.95±0.63 µmol $m^{-2}s^{-1}$ at a light intensity of 1,800 µmol $m^{-2}s^{-1}$. Our results indicated that *S. leprosula* had a higher photosynthetic rate which improved height and diameter growth when planted in a gap compared to trees planted under shade.

Keywords: Rehabilitation, growth, photosynthetic rate, irradiation, adaptation

INTRODUCTION

Unsustainable logging activities and land-use change have resulted in deforestation and forest degradation that affect the economic and ecological values of forests. Since 1990, 420 million hectares of forests were lost due to deforestation although the rate of deforestation has shown a declining trend (FAO, 2020). These consequently cause the loss of essential ecosystem services, including watersheds, carbon stock, and habitat for diverse flora and fauna.

In order to protect and sustainably manage forests, human intervention in planting native or fast-growing species is vital to reduce the impacts of soil erosion, encourage natural succession, and restore the functions of forest ecosystems. Enrichment planting using forest species with high conservation or commercial value also contributes to restoring logged-over areas that are low in growing stock. These efforts are parallel to the commitment of Malaysia in ensuring at least 50% of its total landmass is under forest cover as pledged during the UN Earth Summit in Rio in the year 1992.

The success of any rehabilitation project can be evaluated through the survival and growth of those plants. Nevertheless, these efforts may not provide a suitable condition or environment for natural regeneration that restores the forests' original structure and ecosystem functions. Thus, species-site matching is crucial besides appropriate silviculture treatments at the early stage of plant growth. The interaction of plants with the surrounding environments will create unique microclimate conditions that may favour natural regeneration or succession.

Lentang Forest Reserve (LFR) is located in the state of Pahang, Malaysia. Part of the forest was cleared due to illegal farming. The affected forest area has been planted with various local forest species since 2017 by the Forest Department of Peninsular Malaysia and silvicultural treatments were carried out at regular intervals. LFR has a mosaic landscape with some previously planted areas with some areas having existing pioneer species providing some shade for the new plantings. Meanwhile, opened areas created gaps that give the planted trees more ambient light.

Among the planted trees are *Shorea leprosula*, a Dipterocarpacea, which is of particular interest to the authors due to its good quality timber. This species has been used for enrichment planting and reforestation in Malaysia (Lee & Alexander 1996).

MATERIALS AND METHODS

Microclimate was monitored using HOBO MX2300 (Onset Computer Corp., Massachusetts, US) with sensors for air temperature and relative humidity quantification. One HOBO unit was installed to determine microclimate effects at each gap site and shade site planted with *S. leprosula*. Monitoring of both parameters was carried out for 12 months whereby data were logged at every 15 minutes interval for 24 hours daily. All data collected by HOBO units were downloaded into a handphone via Bluetooth.

Tree height and diameter at breast height (dbh) were measured for six months. Meanwhile, measurements of all physiological parameters were made on the first fully expanded leaves of *S. leprosula* planted in gap (sun tree) and under shade (shade tree). For determination of leaf area, margins of selected leaves were traced on paper before being cut and measured using a leaf area meter (Delta T). Net photosynthetic rate (Pn) was measured using a hand-held photosynthesis system (LI-6800, Licor, Nebraska, USA) under increasing irradiances up to 1,800 µmol $m^{-2}s^{-1}$. Leaf chamber temperature was maintained at 27°C with a CO_2 concentration of 400 ppm.

RESULTS AND DISCUSSION

Throughout the monitoring duration of 12 months, it was found that the mean air temperature was lowest in the month of December whereas June recorded the highest mean readings. Daily variations of air temperature are shown in Figure 1. The lowest mean air temperature recorded in gap and shade sites were about 19°C and 20°C, respectively while the highest mean air temperatures were about 30°C and 27°C, respectively. The results thus showed that the air temperature in the shade area had a lower mean difference of about 3°C at noon time compared to gap area. The lowest mean relative humidity recorded in gap and shade was about 72% and 77%, respectively.

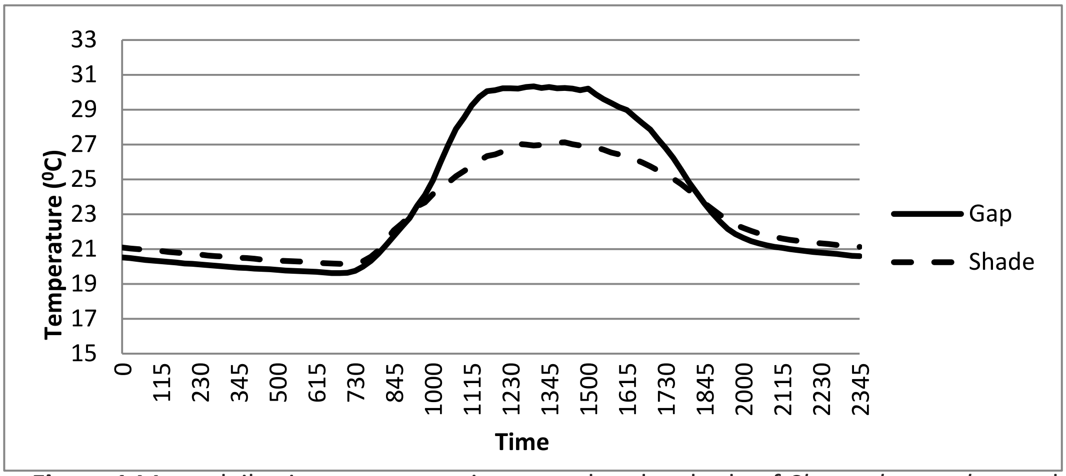

Figure 1 Mean daily air temperature in gap and under shade of *Shorea leprosula* stands

The mean increment in diameter and height of *S. leprosula* measured for six months are shown in Table 1. Further measurements could not be conducted as two of the three trees measured were destroyed by wildlife. Results indicated that trees planted in gaps had better growth in terms of height and dbh compared to those planted under shade.

Table 1 Mean increment in height and diameter at breast height (dbh) for *Shorea leprosula* in gap and under shade for six months

	n	Gap	Shade
Height increment (cm)	3	106.67 ± 16.80	41.67 ± 19.86
Dbh increment (mm)	3	10.06 ± 6.95	9.01 ± 3.98

Net photosynthetic rates (Pn) of *S. leprosula* planted in sun and shade were found to show a significant difference from light intensity (photosynthetically active photon flux – PPFD) at 200 µmol $m^{-2}s^{-1}$. The latter trees had higher Pn at lower light intensity. This agrees with Li et al. (2014) that the maximum Pn of the plants under low irradiance was greater than plants grown under high irradiance. Trees grown under shade had Pn up to 40% higher compared to trees in gap until about 900 µmol $m^{-2}s^{-1}$ where the trend reversed. Leaves of *S. leprosula* trees planted in shade, therefore, have shown the ability to maximise photosynthesis at lower light intensities. Trees under shade achieved maximum Pn at PPFD of 800 µmol $m^{-2}s^{-1}$ whereas trees in gap had maximum Pn at 1,400 µmol $m^{-2}s^{-1}$. The trees in gap continued to show increasing Pn at higher light intensity until 1,800 µmol $m^{-2}s^{-1}$. This explains the better growth of *S. leprosula* when planted in gap. Tirkaamiana et al. (2019) also showed that wider planting space with higher light intensity significantly increased the diameter growth of *S. leprosula*.

CONCLUSION

In this study, we found that the microclimate of gap and shade areas differ in terms of air temperature and relative humidity. The area under shade had lesser variation compared to the area in gap. Our results also indicated that *S. leprosula* was able to adapt to sites with high light intensity or in open areas with better growth compared to when planted under shade. Although these trees have shown to grow well in the rehabilitated site, restoration efforts must also include plans to overcome the attack on trees by the wildlife which can cause serious destruction.

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EFFECTS OF MULCHING ON SOIL QUALITY AND TREE GROWTH PLANTED IN LENTANG AND TERLA FOREST RESERVE , PAHANG

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The study was conducted to investigate the effect of organic mulches from coconut husk and oil palm husk on the growth of selected trees planted in Lentang Forest Reserve and Terla Forest Reserve. Application of commercial plastic sheets as mulch and without mulching as control was also included as a comparison. Soil properties were analysed for six months after treatment while survival rate and tree growth were observed for one year. Although the study areas were hilly and soil disturbance was observed, it was found that the planted tree survived well after one year of planting. The area had an acidic soil pH and low soil nutrients which might have influenced the slow growth increment. However, the use of organic mulch did not have any significant effect on the soil properties and height increment of the planted trees throughout the observation period of this study.

Keywords: Mulching, Lentang Forest Reserve, soil pH

INTRODUCTION

Due to the limited availability of agricultural land for planting, it is important to seek other alternatives such as degraded areas. Planting trees in degraded sites is a challenge that requires an understanding of the factors needed by the trees to ensure the success of planting. Mulching is one of the options available for soil improvement when planting trees on problematic soil. According to Wan Asma et al. (2011), organic mulching would improve the micro-environment of the rhizosphere or root zone thus improving the root development which then boosts nutrient uptake. Besides that, mulching could also regulate nutrient leaching. Organic mulches can also improve soil fertility as they decompose and biodegrade, releasing nutrients into the soil for plant uptake. These organic materials applied to the soil surface help retain moisture and improve soil condition (Rozita et al. 2009). There are now a variety of environmentally friendly, degradable materials that can be used as mulch. Agriculture wastes such as coconut husk, oil palm empty fruit bunches, and rice straws are some of the alternatives. A study on environmentally friendly organic mulch was carried out as an alternative to the commercially available plastic sheet cover. This study compares mulch made from several materials, namely plastic, coconut and oil palm husk on planted tree species on degraded sites at Lentang Forest Reserve and Terla Forest Reserve. Observations on growth patterns and the effects of organic mulch on soil properties were made. The use of environmentally friendly mulch is expected to add value to the agricultural wastes in the country.

MATERIALS AND METHODS

A study on the mulching application on degraded sites was conducted at Lentang Forest Reserve (FR) and Terla FR, Pahang. Lentang Forest Reserve is an exploited and abandoned hilly area. The site is overgrown with grass and weeds that compete with the growth of planted trees. The species selected in this study is *Dipterocarpus cornutus* or locally known as keruing gombang. Terla FR is another hilly, disturbed area due to land clearing activities where the soil in the upper part of the hill was removed. This area was planted with *Magnolia champaka*. In this study, three types of mulching were used namely plastic cover and organic mulch made from coconut and oil palm husk. These mulches were placed according to the experimental layout of a randomised complete block design for both areas. Observations on the survival rate and height of planted trees were carried out for one year of treatment.

Soil samples were collected after six months of application, at two depths, 0-10 cm and 10-30 cm for every treatment. The samples collected were brought to the soil laboratory at FRIM for analysis. They were oven-dried, ground, and sieved through a 0.2 mm sieve. The soil acidity was measured on a pH meter using a 1:2.5 ratio of soil/water suspension. Total nitrogen (N) was determined by Micro Kjeldahl digestion followed by distillation and titration with 0.1N HCL. Available phosphorus (P) was extracted by Bray and Kurtz no.2 procedure and its concentration was measured on a UV-Visible spectrophotometer using Denige Blue method. Exchangeable potassium (K) was extracted using 1N ammonium acetate and its concentration was determined on an Inductive Couple Plasma Optical Emission Spectrometer.

RESULTS AND DISCUSSION

The study showed that the survival rate of *D. cornutus* in Lentang FR over a period of one year was more than 90%. The average height for the control plot, plastic cover, coconut husk, and oil palm husk was 184.2 cm, 174.9 cm, 189.1 cm, and 180.9 cm, with an average growth increment recorded as 77 cm, 72.3 cm, 76.3 cm, and 72.5 cm respectively. While at Terla FR, *M. champaka* observed in the study plot showed 100% survival. The average tree height after one year for control, plastic cover, coconut husk, and oil palm husk were 149.6 cm, 150.8 cm, 146.6 cm, and 153.7 cm, with an average growth increment of 7.7 cm, 8.4 cm, 9.7 cm, and 8.1 cm respectively. The growth rate was found to be relatively slow in Terla FR, and the planted trees were observed to have dry shoots. Overall, there was no significant difference in growth increment among all the treatments. According to a study by Alexander & Stuart (2002), the addition of mulch significantly improved the growth of *D. aromatica* and *S. parvifolia* planted at Sampadi. However, it did not affect the growth of *S. parvifolia* at Balai Ringin when compared to the control. Another study using mulch mat from empty fruit bunch (EFB) had a positive response on the growth of *Orthosiphon stamineus* (misai kucing) on problematic soil but the results did not favour using acacia bark mulch (Rozita et al. 2009).

Table 1 shows the selected soil properties six months after the application of different mulches in the two study areas. Both locations have an acidic pH with values of about 4. The nutrient contents of N, P, and K in the soil samples were in the low range but Terla FR had the lowest readings compared to Lentang FR. This may be attributed to land clearing activities that occurred in Terla FR.

Furthermore, at acidic soil pH, nutrients in the soil may become unavailable for plant uptake. On the other hand, soil nutrients from Lentang FR showed higher values as this site was overgrown with grass and weeds. Based on the results of this study, it was found that organic mulch from coconut and oil palm husk did not show a significant difference in soil properties compared to control and treatment with a plastic sheet. This might have resulted in insignificant growth of *D. cornutus* and *M. champaka* among all the treatments. The duration of research conducted in Lentang FR and Terla FR was too short to show any significant results on the growth performance and soil nutrients. Furthermore, information on mulching applications in disturbed and hilly areas is scarcely reported. Many researchs related to mulch were done in closed environments for instance at nurseries.

Table 1 Selected soil properties with different mulch materials after six months of application

Location	**Treatment**	**Soil depth (cm)**	**pH**	**Nitrogen (%)**	**Available P (ppm)**	**Exch. K (cmol/kg)**
Lentang Forest Reserve	Control	0-10	4.2	0.24	9.5	0.3
		10-30	4.1	0.17	3.6	0.2
	Plastic	0-10	3.9	0.24	7.4	0.3
		10-30	4.0	0.21	5.4	0.3
	Coconut	0-10	4.2	0.21	5.1	0.4
		10-30	4.1	0.16	3.8	0.2
	Oil palm	0-10	4.1	0.22	6.0	0.3
		10-30	4.0	0.16	3.0	0.2
Terla Forest Reserve	Control	0-10	4.3	0.008	5.0	0.1
		10-30	4.2	0.001	3.9	0.1
	Plastic	0-10	4.4	0.005	3.7	0.2
		10-30	4.4	0.003	2.3	0.1
	Coconut	0-10	4.2	0.002	2.9	0.2
		10-30	4.3	0.006	3.5	0.2
	Oil palm	0-10	4.1	0.003	3.2	0.2
		10-30	4.2	0.003	3.4	0.2

CONCLUSION

Despite the sites being degraded due to land clearing, being exploited, and being abandoned, the planted trees showed a good survival rate. The soil had an acidic pH which might have influenced the nutrient availability resulting in slow growth, especially at Terla FR. However, there were no significant differences in soil quality and growth increment among different types of mulch in this study. An extended duration of study for monitoring the soil properties and tree growth is recommended to distinctly observe the impact of different types of mulches used.

ACKNOWLEDGEMENT

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Management Branch, FRIM for assisting in sample collection, monitoring, and laboratory analysis is highly appreciated.

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DEVELOPMENT OF *IN VITRO* PROPAGATION PROTOCOL FOR *NEPHENTES AMPULLARIA*

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Nephentes ampullaria Jack is a carnivorous plant found in Malaysia, Borneo, Maluku Islands, New Guinea, Sumatra, and Thailand. Urban development and human activity have had an impact on the natural habitat of this unique plant. Pitchers of *N. ampullaria* commonly used for "*Lemang periuk kera*" in Malaysia. Although the status of *N. ampullaria* in the Red List is Least Concern (LC), it is becoming increasingly difficult to find the plant day by day. Tissue culture is an alternative way to propagate and replant it in its habitat and to produce its pitchers for *lemang* production. FRIM has made proactive initiative to produced tissue culture plants of *N. ampularia* for conservation as well as for commercial production of this species. In this study, seeds of *N. ampullaria* were used as explants for *in vitro* germination. Germinated plantlets produced were used further as explants for shoot multiplication. In this study, different concentration of Benzyl amino purine (BAP) ranging from (0, 0.5, 1.0, 2.5, and 5.0 mg/L) in MS basal media were used as plant growth regulator for shoot multiplication of *N. ampullaria*. For *in vitro* rooting, three basal media (½ MS, ½ WPM and ½ B5) with four different IBA concentration (0, 0.5, 1.0, and 2.5 mg/L) were used. Cotyledonary seedlings were cultured in these media and incubated in culture room at a temperature of 22.0 ± 2.0°C. After 8 weeks, all cultures were observed, and data obtained were analysed using the Duncan's Multiple Range Test (DMRT). Results obtained showed that the MS basal medium added with 2.5 mg/L BAP is the most suitable medium for shoot multiplication and ½ WPM basal medium containing 2.5 mg/L IBA produced the highest mean number of roots. Plantlets produced were successfully acclimatised in the nursery.

Keywords: *Nephentes ampullaria*, tissue culture, shoot multiplication, *in vitro* rooting

INTRODUCTION

Nepenthes sp. belongs to the Nepenthaceae family of the order Nepenthales. In Malaysia, this plant has various local names namely pitcher plant or periuk kera (Malay, Peninsular Malaysia), somboi-somboi (Malay, Brunei), tetuyud (Melanau, Sarawak), entuyud (Iban, Sarawak) and kekuanga (Dusun, Sabah). *Nepenthes* sp. is a climbing plant and sometimes creeping. It is also a dioecious plant i.e., male and female flowers are found on separate trees (Adam et al. 2004).

People had collected these plants including *N. ampullaria* for their unique pitcher and horticultural values. The pot-like pitchers of *N. ampullaria* can conveniently be used to cook rice and are said to impart an appetizing flavour to the rice and the special dish "lemang periuk kera" is made by adding rice into the pot-like pitcher. It is usually served and prepared during the festive season like *Hari Raya Aidifiltri* and other festivals.

The status of *N. ampullaria* was classified as Least Concern (LC) according to the Red List. However, the natural habitat of *N. ampullaria* had been disturbed due to human activities and space clearing for the development of the city. Improper methods of harvesting *N. ampullaria* pitcher can also affect the population of this species. To make "lemang periuk kera" only the appropriate pitcher size should be harvested instead of the whole plant.

FRIM has produced *N. ampullaria* tissue culture plants for conservation, commercial production, and restoration of its population to the wild habitat. Propagation by tissue culture will ensure the planting material is obtained without harming the existing habitat. *In vitro* propagation will also be the fastest way to propagate this species as it is known to be a naturally slow-growing plant. Thus, the main objective of this study is to develop a tissue culture protocol for *N. ampullaria* planting material production as well as for conservation.

MATERIALS AND METHODS

Surface Sterilization and *In Vitro* Germination

Fruits of *N. ampullaria* (Figure 1) were collected from Tanjung Malim, Perak. Seeds were surface sterilized using 70% Clorox® for 20 minutes and washed three times with sterile distilled water. The seed coat was peeled off then the seeds were cultured in MS (Murashige & Skoog) basal medium containing 0.5 mg/l BAP and incubated in a culture room at a temperature of 22.0 ± 2.0°C for *in vitro* germination.

Shoot Multiplication

The *in vitro* germinated seedlings produced were used as explants for shoot propagation experiments. Three-leaf seedlings were used as explants and cultured in MS basal medium supplemented with different concentrations of Benzyl Amino Purine (BAP) (0, 0.5, 1.0, 2.5, and 5.0 mg / L). The average pH was adjusted to 5.8 before autoclaving. Five bottles of medium were prepared for each treatment, and each bottle contained three explants. All cultures were incubated in a culture room at a temperature of 22.0 ± 2.0°C for shoot multiplication. The number of induced shoots per explant was observed after 8 weeks in culture.

In Vitro Rooting

Three basal media (½ MS, ½ WPM, and ½ B5) with four different Indole Butyric Acid (IBA) concentrations: (0, 0.5, 1.0, and 2.5 mg/L) were prepared and used for root induction *in vitro* to produce complete plantlet. The average pH was adjusted to 5.8 before autoclaving. *N. ampullaria* individual shoots were subcultured into these media with 15 replicates for each treatment. All cultures were incubated in a culture room at a temperature of 22.0 ± 2.0°C for *in vitro* rooting. The numbers of roots produced were observed after 1 month of culture.

Acclimatisation of Plantlets in the Nursery

Plantlets of *N. ampullaria* were washed with sterile distilled water and roots were dipped in fungicide to prevent fungal contamination. Plantlets were then put in a different potting medium which is sphagnum moss, sand, and baked soil combined with peat moss and acclimatised for one month in the acclimatisation chamber for the hardening process before transfer to the polybag.

Data Analysis

Analysis of data was carried out using SAS version 9.1.2.

RESULTS AND DISCUSSION

***In Vitro* Germination**

After two weeks in culture, it was observed that clean culture was obtained, and all seeds started to germinate *in vitro*. *In vitro* germinated plantlets were used later as explants for the shoot multiplication experiment (Figure 1).

Figure 1 Fruits of *N. ampullaria*

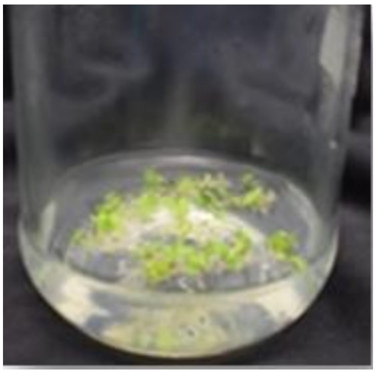

Figure 2 *In vitro* germinated seedling

Shoot Multiplication

Shoot multiplication of *N. ampullaria* was observed after 8 weeks in culture. There was a significant difference between MS basal medium supplemented with BAP or without BAP. Among the five treatments, it was observed that MS basal medium supplemented with 2.5 mg/L BAP produced the highest mean shoot numbers (2.8 ± 0.26) (Figure 3). Results showed that shoots were increased directly proportional to the increment of BAP concentration from 0 mg/L BAP to 2.5 mg/L BAP but decreased after that.

Budisantoso et al. (2018) also reported that the addition of BAP to a certain concentration in ½ MS basal medium promotes the development of *N. ampullaria* new bud but after the optimum concentration, it showed negative effects. The optimum medium for shoot multiplication and shoot regeneration of *N. ampullaria* in this study is MS basal medium containing 2.5 mg/L BAP. Meanwhile, it was observed that MS basal medium supplemented with 1.0 mg/L BAP had a very significant effect on the leaf length.

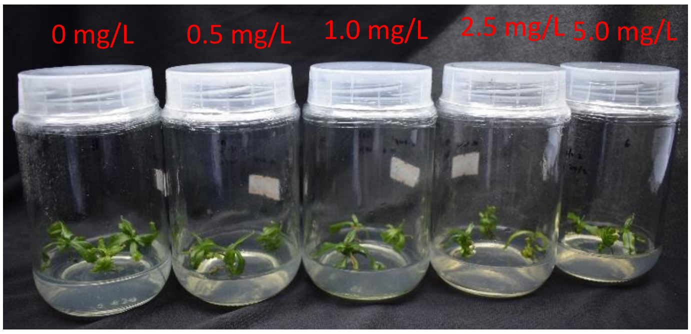

Figure 3 Shoot multiplication of *N. ampullaria* in different BAP concentration

***In Vitro* Rooting**

After 1 month in culture, it was observed that all basal media used in this study can promote root growth for *N. ampullaria* and produced a complete plantlet (Figure 4). An increment of IBA concentration in all basal media showed a positive response in which ½ WPM basal medium added with 2.5 mg/L IBA (Figure 5) produced the highest mean number of roots. The roots length is inversely proportional to the number of roots produced.

Figure 4 Complete plantlets of *N. ampullaria* produced *in vitro*

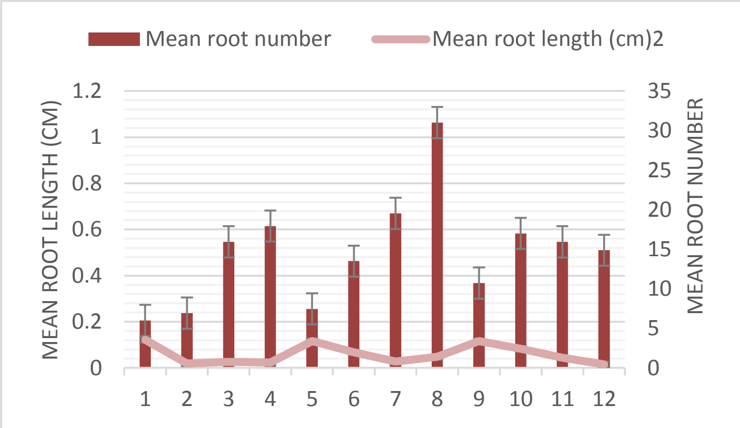

Figure 5 Effects of different medium to *in vitro* rooting of *N. ampullaria*

Acclimatisation of *N. ampullaria* Plantlets in the Nursery

N. ampullaria plantlets were successfully acclimatised in the nursery after 1 month in all potting medium tested (Figures 6 & Figure 7).

Figure 6 Acclimatisation of *N. ampullaria* plantlets in different potting media

Figure 7 Successful acclimatized plantlets in different potting medium

CONCLUSION

In vitro propagation protocol of *N. ampullaria* was developed and can be used for the production of planting material.

ACKNOWLEDGEMENT

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THE DEVELOPMENT OF DETECTION METHOD FOR GENETICALLY MODIFIED BRINJAL (*SOLANUM MELONGENA* L.)

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Brinjal or eggplant (*Solanum melongena* L.) is an important vegetable crop in subtropics and the tropics. It is beneficial for human health because of its high fiber and water content, rich in anti-oxidants, and a good source of vitamin and minerals. Despite its potential as a commercial vegetable crop, brinjal is susceptible to many diseases and pests, including eggplant fruit and shoot borer. The genetically modified brinjal or known as *Bt* brinjal has been developed to give resistance against lepidopteron insects, in particular the Brinjal Fruit and Shoot Borer (*Leucinodes orbonalis* Guenée). The Bt brinjal termed as Event EE-1 was developed by the Maharashtra Hybrid Seeds Company (Mahyco), India. It contains an insect resistance gene (*Cry1Ac*) under the control of CaMV promoter and NOS terminator, with *nptII* gene as the selectable marker. Brinjal is one of the commonly consumed vegetables and has been continuously imported to meet the local market's demand in Malaysia. Therefore, it is crucial to develop effective and accurate analytical methods for Bt brinjal detection so that compliance with Biosafety Act 2007 in Malaysia is ensured. The objective of this project is to validate and screen event-specific methods for Bt brinjal detection using conventional and real-time PCR methods for its application in Malaysia. This project has successfully validated the method of event-specific EE-1 brinjal detection by simplex, multiplex, and real-time PCR as reported by Ballari et al. in 2012 with slight modification. EE-1 primer has been verified to exclusively amplify the DNA of event EE-1. The sensitivity of EE-1 primer showed the limit of detection as low as 0.1 pg. The methods developed are ready for Bt brinjal detection in Malaysia and are hoped could assist the Department of Biosafety in better regulating the Living Modified Organism (LMO) activities in Malaysia.

Keywords: LMO detection, *Bt* Brinjal, PCR

INTRODUCTION

Brinjal is an important vegetable crop and is grown extensively in India, Bangladesh, Pakistan, China, and the Philippines as well as in the warm temperate zones, especially in Southern Europe and the Southern United States. However, brinjal is susceptible to many diseases and pests, including the eggplant fruit and shoot borer (EFSB, *Leucinodes orbonalis* Guenée). EFSB is a medium-sized moth (Lepidoptera: Crambidae) whose feeding larvae cause damage to the brinjal crop by boring into stems and fruits. Yield, therefore, can be affected either by severely damaged or destroyed fruits or by damage to the developing plant. EFSB has been described as the most serious and destructive pest to brinjal crops (Parimi & Zehr 2009). The Report of the Expert Committee (EC-II) on Bt Brinjal submitted to the Indian government (GEAC, 2009) described losses of between 60-70%, even when insecticides were used.

In view of the pest and diseases serious problems, the genetically modified brinjal or more known as *Bt* brinjal has been developed to give resistance against lepidopteron insects, in particular the EFSB. The genetically modified brinjal event is termed EE-1. The *Bt* brinjal is transgenic brinjal created by inserting a crystal protein gene (*Cry1Ac*) from the soil bacterium *Bacillus thuringiensis* into the genome of various brinjal cultivars. The insertion of the gene, along with other genetic elements such as promoters, terminators, and an antibiotic resistance marker gene into the brinjal plant is accomplished using *Agrobacterium*-mediated genetic transformation.

Bt brinjal has undergone field evaluation by a national hybrid seed company in India and further progress into backcrossing Event EE-1 into locally adapted brinjal. Open-pollinated brinjal varieties have recently been made in the public sector (MOEF 2010). The technology has also been passed on to the public sector in the Philippines, where multi-location field trials are in progress (IPB 2011), as well as both public and private sectors in Bangladesh (MOEF 2010). General concerns over transgene escape were incorporated into the Cartagena Protocol on Biosafety to the Convention on Biological Diversity (SCBD 2000) to which Bangladesh, India, and the Philippines are signatories. Early in 2010, the Indian government incurred a moratorium on the commercialisation of *Bt* brinjal in India, which still continues.

Given the scenario of the said *Bt* Brinjal, it is crucial to develop effective and accurate analytical methods for this genetically modified brinjal detection so that compliance with Biosafety Act 2007 in Malaysia is ensured. Such method has been developed by Ballari et al. CSIR-Central Food Technology Research Institute, India. Single and multiplex PCR methods based on the event of EE-1 brinjal have been developed using both standard and real-time PCR (qPCR). This project is aimed to validate the method for its application in Malaysia. Findings from this study would provide essential information which could assist the Department of Biosafety (JBK) in better regulating LMO activities in Malaysia.

MATERIALS AND METHODS

EE-1 Brinjal Materials

EE-1 brinjal seed labeled as T-64 was provided by the Department of Biosafety (JBK). The seed was from Bangladesh which was restricted only for research purposes.

Primer Synthesis

Primers reported in Ballari et al. (2012), Randhawa et al. (2012), Char & Ghandi (2016), and Cheema et al. (2016) were used in this project. The primer sequences were synthesised by Apical Scientific Sdn Bhd.

DNA Extraction

Brinjal seeds were lysed using tissue lyser (Qiagen, Germany) and the genomic DNA was extracted using DNeasy Plant Mini Kit (Qiagen, Germany). The extracted DNA was quantified using NanoDrop 2000 spectrophotometer (Thermo Scientific, US).

PCR Amplification

PCR mixture in a total volume of 10µL comprised 5 uL exTen PCR Mastermix (1st BASE, Malaysia), 1µL of DNA sample, and 0.5 µL of 10 mM forward (F) and reverse (R) primers. PCR reaction was carried out in a thermal cycler (SimpliAmp, Applied Biosystems, USA). The amplified products were analyzed under 2% agarose gel electrophoresis supplemented with 0.1% GelRed in 1xTAE buffer for 45 min at 100V and visualized using AlphaImager MINI (Cell Biosciences, Australia).

DNA Sequencing for Validation of EE-1 Brinjal

DNA sequencing was carried out to further confirm the EE-1brinjal. 685 bp region of EE-1 brinjal that consists part of *Cry1Ac* gene flanked by the 7S terminator, T-DNA right border, and brinjal genomic DNA was amplified using EE-1- 685 primer (Char & Ghandi 2016). Fragment obtained was purified using MinElute Gel Extraction Kit (Qiagen, Germany) and ligated into pCR®2.1. The recombinant plasmid was then transformed into TOP10 competent cells for multiplication and extracted using QIAprep Spin Miniprep kit (Qiagen, Germany).

Plasmid DNA was sequenced using respective forward or reverse primer and the BigDye Terminator Sequencing Kit (Applied Biosystems). Sequencing was performed on the ABI 3130xl Genetic Analyzer (Applied Biosystems). The raw sequences were analyzed using SEQUENCHER version 5.3 (Gene Codes Corporation) and aligned using the multiple sequence alignment tool of BLASTN. The reference sequence of EE-1 brinjal was obtained from patent document WO2007/091277 (Char & Ghandi 2016).

Multiplex PCR Optimisation

DNA templates used in multiplex PCR were EE-1 brinjal, CRM MON531, and GM corn from the previous project. Multiplex PCR reaction mixture comprised of 1 X PCR master mix (exTEN PCR master mix, 1st Base), 0.2 – 0.6 uM of each primer (aadA2, NOS, Cry1Ac, BtB-nptII, BtB-NOS and EE-1) and 100 ng of template DNA in a total volume of 25 uL. The PCR products were analyzed under 2.5% agarose gel electrophoresis supplemented with 0.1% GelRed in 1xTAE buffer for 80 min at 100V and visualized using AlphaImager MINI (Cell Biosciences, Australia).

SYBR Green Real Time PCR (RT-PCR)

The real-time PCR assay was performed using 7500 Fast Real-Time PCR v.2.3 software (Applied Biosystems, Foster City, CA, USA). Amplification efficiency and sensitivity of the qPCR of EE-1 primer were tested using a standard curve and melting curve analysis, respectively. EE-1 brinjal DNA sample was diluted in ten fold serial dilution (1:10 to 1:10,000) in nuclease-free water. qPCR was performed in a 25 µL reaction volume consist of 1 µL of each diluted sample, 10 µL of PowerUP SYBR Green Master mix, and 0.5 µL of EE1 F/R primers. All reactions were performed in triplicate.

Determination Limits of Detection and Specificity

Limit of detection (LOD) was detected by performing amplification of serial dilutions of EE-1 brinjal DNA at concentrations of 10 ng to 0.1 pg μL^{-1}. While the specificity of EE1 F/ R primer pair was evaluated using genomic DNA extracted from other genetically modified plants which were *Bt*176 maize, *Bt*11 maize, RT73, MON89034 maize, MON89786 soya, MON863 soya, MON531 cotton, and soybean (tested GM in our lab).

RESULTS AND DISCUSSION

Validation of T-64 Brinjal is EE-1 Brinjal

EE-1 brinjal contains recombinant construct as illustrated in Figure 1 which consist of 35S promoter (P-35S), npt II selective marker gene (nptII), NOS terminator (T-NOS), aadA gene selective marker gene (aadA), promoter E35S (P-E35S), Cry1Ac gene (Cry1Ac), 7S-3', and T-DNA Right border (T-DNA RB). Validation using PCR showed that DNA samples of T-64 amplified all DNA fragments present in EE-1 brinjal (18S, 35S promoter, NOS terminator, npt II gene, and Cry1Ac gene) (Figure 2).

Plant genome	P-35S	nptII	T-NOS	and	P-E35S	Cry1Ac	7S-3'	T-DNA RB	Plant genome

Figure 1 Schematic representation of recombinant construct present in EE-1 brinjal adopted from Ballari et al. (2012)

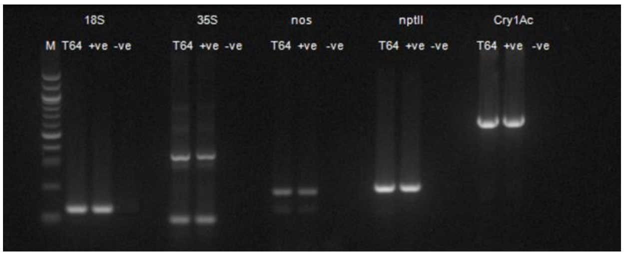

Figure 2 Agarose gel electrophoresis of T-64 amplification products using primer of 18S, CaMV 35S promoter, NOS terminator, *nptII*, and *Cry1Ac* gene. T-64 represented T-64 DNA; +ve is MON531; -ve is negative control without DNA and M is 100 bp DNA ladder

Among PCR-based methods of GM detection, event-specific which refers to the amplification of integration junction between host genome and transgenic DNA sequence is the most specific in GM detection. Thus, to reconfirm the preliminary screening results, T-64 was amplified using EE-1 event-specific primers retrieved from patent document WO2007/091277. EE-1-685 forward primer targets the transgenic region of the *Cry1Ac* sequence, while EE-1-685 reverse primer targets flanking region of the brinjal DNA genome sequence (Figure 3A). EE-1 primer pair generates an expected amplification product of 685 bp for T-64 (Figure 3B), no amplification was found in MON 531 indicating the specificity of EE-1 event-specific primers.

A

B

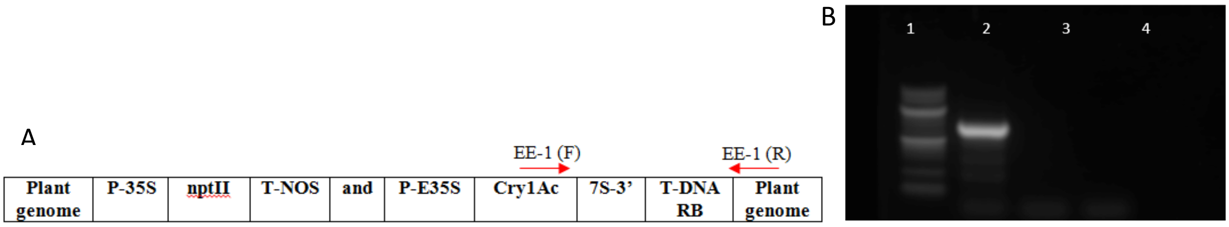

Figure 3 (A) Schematic diagram of recombinant construct of EE-1 brinjal showing arrows to indicate location of EE-1 primer pair used to amplify EE-1 region. (B) Agarose gel electrophoresis of PCR amplification product of T-64 brinjal. Lane 1, 100 bp ladder; lane 2, T-64; lane 3, MON 531; lane 4, negative control

DNA sequencing has successfully sequenced the 685 bp region that consists of the exogenous *Cry1Ac* gene and the brinjal genome. Alignment of the sequence with EE-1 brinjal reference sequence of the patent document O2007/091277 (Char & Ghandi 2016) showed 97.98 % identity. The match to the reference sequence confirms that T-64 brinjal is EE-1 brinjal.

PCR Multiplex Optimisation

Multiplex PCR would allow multiple PCR reactions to be carried out in one reaction (tubes). Two sets of multiplex PCR have been optimized where each set amplified 3 amplicons. Set 1 amplified genes of Cry1Ac (insect resistance gene), aadA (streptomycin resistance gene), and NOS (*Agrobacterium* Nopaline Synthase terminator) (Figure 4A), while set 2 amplified aadA gene and another two DNA fragments which were specific to EE-1 brinjal (Figure 4B). No amplification on CRM MON531 and genetically modified corn indicated the specificity of the fragment to EE-1 brinjal. Thus, the set could be used to detect a specific event of EE-1 brinjal.

A

B

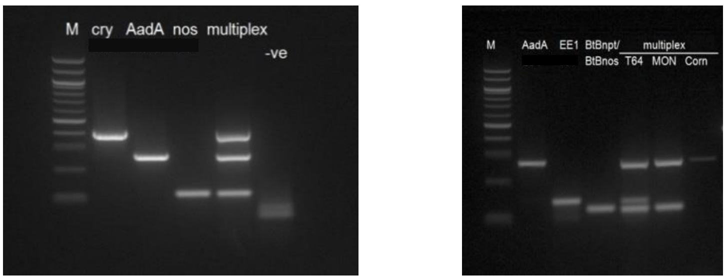

Figure 4 (A) Singleplex and multiplex amplification in set 1 (A) and set 2 (B). Set 1 shows amplification of T-64 (EE-1) brinjal using Cry1Ac (cry), aadA, and NOS terminator (nos). While set 2 shows amplification of aadA and 2 regions of EE-1 brinjal (EE-1 and BtBnpt/BtBnos) for EE-1 brinjal (T64), CRM MON531 (MON) and genetically modified corn (Corn). 'Multiplex' represents amplification of the three genes in one reaction. M is 100 base pair DNA marker and –ve is PCR reaction without DNA sample

SYBR Green Real Time PCR (RT-PCR) Optimisation

Real time PCR qualitative method is considered to be easy, useful, and accurate as compared to normal PCR. A serial dilution of EE-1 brinjal genomic DNA was analyzed using a standard curve method to determine the PCR amplification efficiency of EE-1 primer. The correlation coefficient (R^2) was 0.977, indicating a high correlation between copy number and C_t value. Using the formula Efficiency = $10^{(-1/slope)}$ -1, the PCR efficiency was 92%. The high efficiency and the correlation coefficient of near unity obtained suggest that the method is well suited for quantitative estimation for EE-1 brinjal detection. Melting temperature (T_m) curve analysis performed showed that the plots depict a single peak with a single T_m of 73.7°C indicating the specificity of the primer.

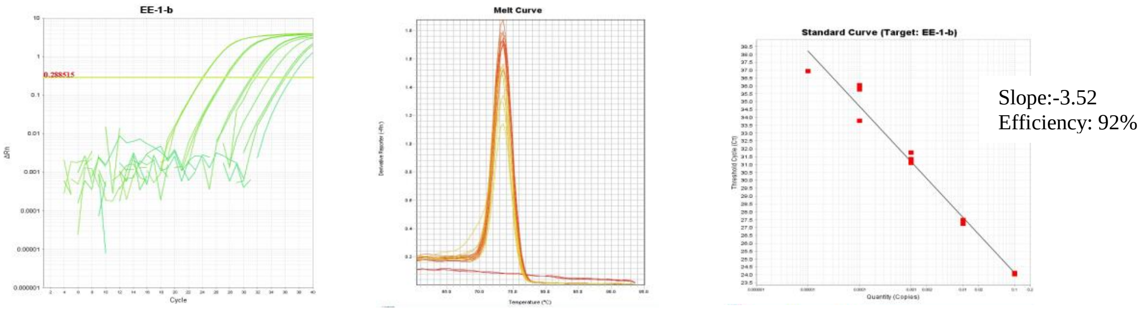

Figure 5 Event-specific real-time PCR for EE-1 brinjal efficiency test. (A) Amplification curves generated by five EE1 brinjal genomic DNA serial dilution of 100 000, 10 000, 1000, 100, and 10. (B) Melting curve analysis of EE1 brinjal shows single specific peak with T_m = 73.7°C. (C) Standard curve showing diluted template vs. threshold cycle (C_t) generated from the amplification data that generated a slope of -3.52 which equivalent to PCR efficiency of 92%

Limits of Detection and Specificity Determination

Limit of detection (LOD) of event-specific PCR assay was tested by performing amplification on serial dilutions of EE-1 brinjal DNA at concentrations of 10 ng to 0.1 pg/ µL. The primer pair EE-1 F/R amplified the desired 151 bp product size in all the test samples down to 0.1 pg as shown in Figure 6. The results indicated that amplification of EE-1 brinjal could be detected in DNA samples as low as 0.1 pg.

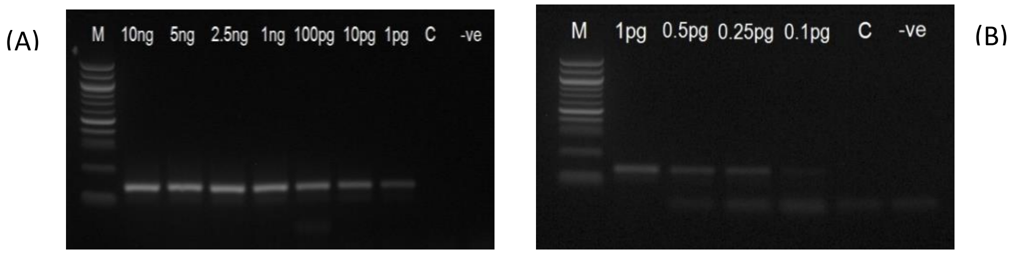

Figure 6 PCR assay for sensitivity test of EE1 F/ EE1 R event-specific primer. (a) Lane 1, 100 bp DNA ladder; lane 2-8, 10ng, 5ng, 2.5ng, 1ng, 100pg, 10pg, 1pg of EE-1 brinjal DNA respectively; lane 9, non-transgenic brinjal; lane 10; negative control. (b) Lane 1 is 100 bp DNA ladder; lane 2-5, 1pg, 0.5pg, 0.25pg and 0.1pg of EE-1 brinjal DNA respectively; lane 6, non-transgenic brinjal; lane 7; negative control

The specificity of primer pair EE-1 F/R was evaluated using genomic DNA extracted from other LMOs. Amplification of the expected size of 151 bp EE-1 was observed exclusively to EE-1 brinjal (T64) whereas no amplification with the expected size of 151 bp was detected in other transgenic lines

(Figure 7). The absence of the amplification product in other transgenic lines indicates the specificity of the primer pair to detect event-specific EE-1 brinjal. A non-specific band was obtained in a few samples might be due to either contamination in the PCR reaction or nonspecific binding of the primer at a lower annealing temperature.

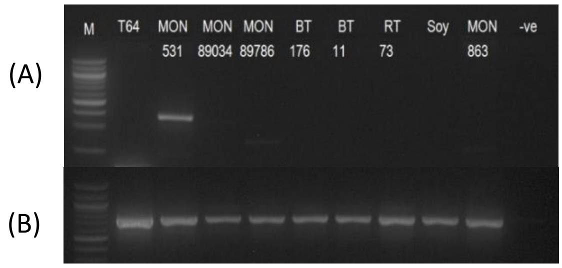

Figure 7 Quantitative event-specific PCR assay of EE-1 brinjal. (A) Agarose gel electrophoresis of PCR amplification product using event-specific EE-1 primer pair. (B) Present of DNA test using plant-specific primer pair rbcL F/R. Lane 1, 100 bp DNA ladder; lane 2-10; EE-1 brinjal (T64), MON531, MON89034, MON89786, Bt176, Bt11, Rt73, Soybean and MON863 respectively; lane 11, negative control

Multiplex PCR was also performed using multiplex set 1 on the other GM transgenic line to further confirm the specificity of the established method. Qualitative multiplex PCR could be used to distinguish between event-specific EE-1 brinjal with other GM transgenic lines (Figure 8). Different amplicon sizes, 284, 151, and 126 bp were generated when using respective primer pairs in multiplex PCR and were able to distinguish under agarose gel electrophoresis. The primer pair EE1 F/R was exclusively detected EE-1 region in EE-1 brinjal.

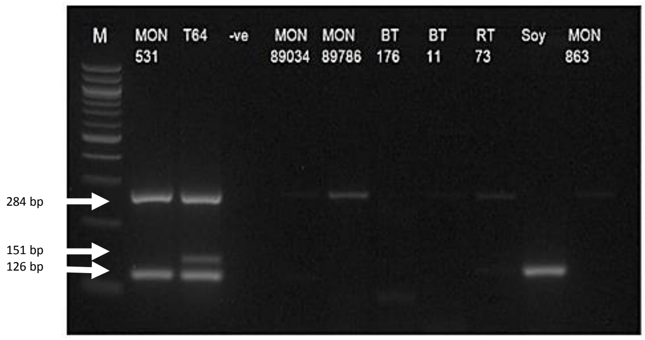

Figure 8 Multiplex PCR assay for detection of EE-1brinjal. Amplification products of multiplex PCR using primer pair of aadA2 F/R, BtB-npt F/ BtB-NOS R and EE1 F/R. M is 100 bp DNA ladder; lane 2-10, MON531, EE-1 brinjal (T-64), MON89034, MON89786, *Bt*176, *Bt*11, RT73, Soybean and MON863 respectively; lane 4 is negative control

CONCLUSION

This study significantly shows that the seed of brinjal labelled as T-64 provided by the Department of Biosafety is EE-1 brinjal after being validated with PCR using primer pairs of targeted elements present in EE-1 gene construct which are CaMV 35S promoter, NOS terminator, *nptII* gene, and

Cry1Ac gene. T-64 was further confirmed as EE-1 brinjal by amplification of the integration region between exogenous *Cry1Ac* gene and brinjal genome using event-specific EE-1 primer. In addition, sequencing was also carried out to further verify the EE-1 brinjal. Alignment of the T-64 brinjal sequence with the reference sequence showed 97.98% identical.

This study successfully validated the method of event-specific EE-1 brinjal detection by simplex, multiplex, and real-time PCR as reported by Ballari et al. (2012) with slight modification. EE-1 primer has been verified to exclusively amplify EE-1 brinjal and not in at least 7 other transgenic plants. The sensitivity of EE-1 primer showed the limit of detection as low as 0.1pg. Two sets of multiplex PCR reactions have been optimized to decrease the cost and reagent in LMO detection. For an easier and more accurate method of qPCR, the high PCR efficiency (92%), and specificity of EE-1 primer have been validated and are ready to be used for EE-1 brinjal event-specific detection. The methods developed are beneficial to detect GM brinjal as well as EE1 specific-event. The methods are important to assist the Department of Biosafety in better regulating LMO activities in Malaysia.

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SYNTHESIS OF NITRATE AND PHOSPHATE-ZINC LAYERED HYDROXIDE NANOHYBRID AND ITS SUITABILITY AS SLOW RELEASE FERTILISER DELIVERY SYSTEM

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Nitrogen (N) and phosphorus (P) fertilisers are mainly applied in the early stages of planting for growth and root development. However, most of the fertilisers applied in agriculture are not fully absorbed by plants as they got lost to the environment through leaching and evaporation which causes environmental pollution and substantial economic losses. Incorporating nitrogen and phosporous sources in layered metal hydroxides (LMH) can minimise the environmental-related problem and fertiliser consumption. LMH can prolong the duration of action of the active agent by delivering it in a slow manner, and as a protection shield by increasing the stability of the active agent through electrostatic interaction in the interlayer region, thus minimising loss from leaching and degradation. In this study, zinc-layered hydroxide (ZLH) nanohybrid containing two plant nutrient sources, nitrate and phosphate was successfully prepared by co-precipitation and anion exchange method. Zinc-layered-nitrate and phosphate nanohybrid (ZLNP) obtained was thermally more stable than its counterpart. The release of nitrate and phosphate from the nanohybrid showed different percentage releases in different media solutions, with higher nitrate anion release than phosphate anion. The nutrient uptake in leaves of kelempayan from nanohybrid treatment showed the highest percentage of N, P and Zn compared to the control and the other two treatments with raw material and commercial fertiliser. The nanohybrid gives the highest seed germination indicating that the material is safe and non-toxic to plants.

Keywords: Layered metal hydroxides, nanohybrid, ferliser

INTRODUCTION

Fertiliser applications are essential in every crop planting for plant growth. They are normally applied to the soil due to insufficient amounts of nutrients for plant uptake. Nitrogen and phosphorous sources of fertiliser are being applied at the beginning of planting to enhance the growth and root development of agricultural and forest timber species. However, they are not fully absorbed by plants as they got lost through leaching and evaporation. The nutrient efficiency of conventional fertiliser used by the plant is reported as 20-50% for N and 10-25% for P fertiliser

(Chinnamuthu et al. 2009). They can enter and contaminate the groundwater causes environmental pollution, leading to economic losses.

Repeated and frequent fertiliser application is a normal practice in crop plantations and this enhances the problem even more. Controlled release formulations (CRF) have been introduced to reduce environmental-related problems by prolonging the release of the active agent. However, some of the CRF materials have limitations as they contain additives such as plasticisers, fillers, antioxidants, and stabilisers that are left behind once the application is completed (Cardarelli et al. 1980). This can contaminate the environment and become hazardous to living things. A suitable CFR material that is environmentally friendly is in a need to minimize pollution and efficiently deliver the active agent in a slow manner.

Zinc-layered hydroxide (ZLH) as controlled release material can store active agents within its interlayer region producing a nanohybrid material with high stability, reducing solubility and degradation. The interlayer anions can be released from its nanohybrid through an anion-exchanged process and partial dissolution of the ZLH layer (Hussein et al. 2012; Cursino et al. 2010). Due to the anion exchange properties of ZLH, the active agent can be released into the environment for plant uptake. Furthermore, ZLH can provide zinc supplement to the soil thus improving soil micronutrients which is beneficial for plant growth. This work will describe a synthesis method for ease preparation of ZLH-fertiliser nanohybrid-containing nitrate and phosphate as plant nutrient sources, which can be potentially applied as a sustained release formulation for an effective fertiliser delivery system.

MATERIALS AND METHODS

Synthesis and Characterization of Nanohybrid Compound

The nanohybrid was synthesized by co-precipitation and anion exchange process using sources of N and P such as zinc nitrate hexahydrate and potassium hydrogen phosphate. Sodium hydroxide aqueous solution (NaOH) was added into zinc nitrate hexahydrate solution until pH 7 with constant stirring at various times. The synthesized material was centrifuged, thoroughly washed with deionised water, and oven-dried. The material then was dissolved in 50 mL of deionised water and mixed with potassium hydrogen phosphate solution. NaOH was added slowly into the mixed solution until pH 8 with constant stirring at various times. The synthesized material ZLNP was centrifuged, thoroughly washed with deionised water, and oven-dried. Different parameters which include chemical concentration, aging condition, and different concentrations of NaOH were studied to obtain the optimise conditions for the preparation of nanohybrid. The produced nanohybrid was characterised by powdered X-ray diffraction (PXRD), Fourier transform infrared spectroscopy (FTIR), flow injection analyzer (FIA), thermogravimetry and differential scanning calorimetry (TGA/DSC), inductive couple plasma spectroscopy (ICP-OES), and field of emission scanning electron microscopy analysis (FESEM).

Controlled Release Study

The controlled release of nitrate and phosphate from the nanohybrid was monitored in soil media solution. The nanohybrid was dispersed in the release media at an appropriate interval of time. The amount of nitrate and phosphate anions in the release media were determined by flow analyzer and ICP-OES method, respectively.

Phytotoxicity Test

The method was adopted from Keeling (1994) to determine the toxicity of the nanohybrid toward plants. The test used extract solution of the nanohybrid on germination of green bean seeds. Distilled water, extract solution of raw material and commercial fertiliser were also tested.

Plant Growth Study

A short-term plant growth study was carried out at FRIM nursery using kelempayan as the test plant. A control without any chemical was conducted together with, ZLNP, raw material, and commercial fertiliser. The plant seedlings were germinated on a sand bed for two months and transferred in a polybag containing normal soil media with four different treatments of twenty replications per treatment. The height of the plant was measured at every one-month interval for a period of four months. Destructive sampling was carried out 4 months after planting. Biomass yield was measured and the nutrient analysis was carried out to determine the plant nutrient uptake (N, P, and Zn).

RESULTS AND DISCUSSION

Physico-Chemical Properties

Figure 1 exhibits the PXRD pattern of the synthesized zinc-layered hydroxide nitrate and phosphate nanohybrid (ZLNP). The pattern shows the formation of nitrate and phosphate of ZLH with a sharp reflection peak at the basal spacing, 9.57 Å (Arizaga et al. 2008) and 6.78 (Woo et al. 2011), respectively. The ZLNP indicated a high crystalline structure in the 2ϴ angles at 0–60^{o} range.

The existence of nitrate and phosphate ions in ZLH was further confirmed by the FTIR study as shown in Figure 2. A sharp band at 1384 cm^{-1} can be assigned to the vibration mode of the nitrate ion. The absorption band at 635 cm^{-1} referred to the stretching vibration of oxygen-hydrogen. While the 3436 cm^{-1} band is related to hydroxyl groups of water molecules in the ZLH interlayer (Machado et al. 2010). FTIR spectra of phosphate at 1000 cm^{-1} band can be attributed to phosphate ion vibration (Woo et al. 2011). Figure 3 shows the morphology of ZLNP obtained by FESEM. The image displays a non-uniform with a flat shape structure which tallies with the crystallinity recorded by PXRD measurement.

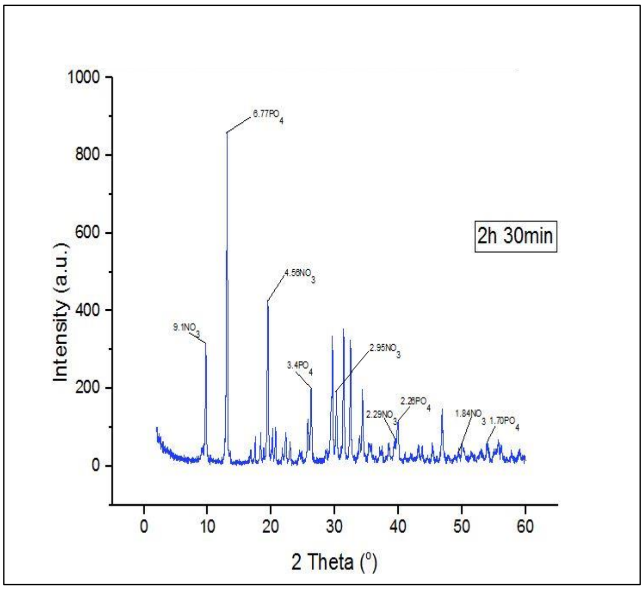

Figure 1 PXRD result pattern of ZLNP

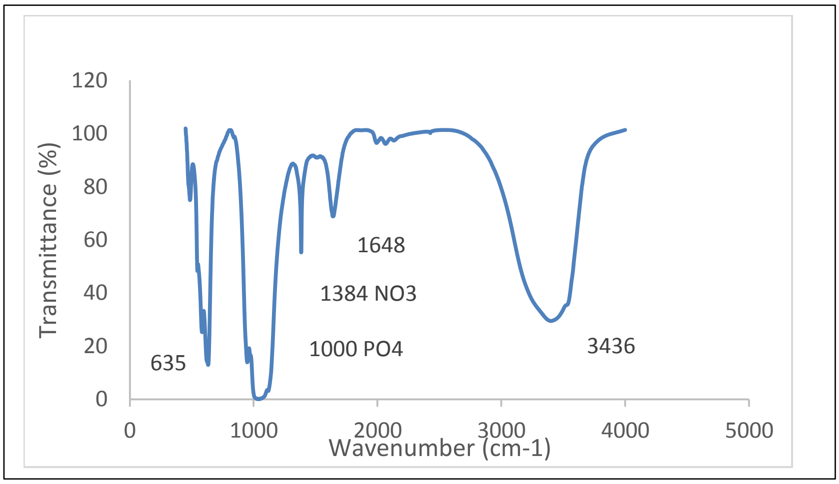

Figure 2 FTIR spectrum of ZLNP

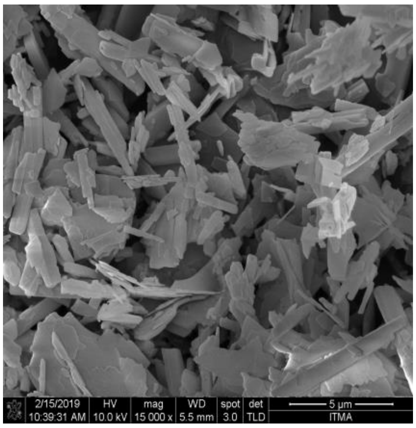

Figure 3 FESEM micrograph of ZLNP at 15,000 magnifications

The TGA analysis was carried out to determine the stability of ZLNP against thermal decomposition. Figure 4 shows the TGA/DSC thermograms of ZLNP. The thermal decomposition of ZLNP progresses through three major stages of weight loss, occurring at temperature maxima of 110°C, 170°C, and 320°C with weight losses of 3.9 %, 6.6%, and 10.5%, respectively. The first stage of weight loss is due to the removal of water molecules from the ZLH (Cursino et al. 2010). The second weight loss is due to dehydroxylation of hydroxide layers as well as partial decomposition of the intercalated nitrate and phosphate anions at 170 °C. An increase in the temperature to 320 °C is related to the decomposition of inorganic anions leaving less volatile metal oxide (He et al. 2010). This indicates better thermal stability of nitrate and phosphate anions in ZLNP. The obtained nanohybrid determined by N-analyzer and ICP OES contained nitrate and phosphate of 20.6% and 12.58%, respectively.

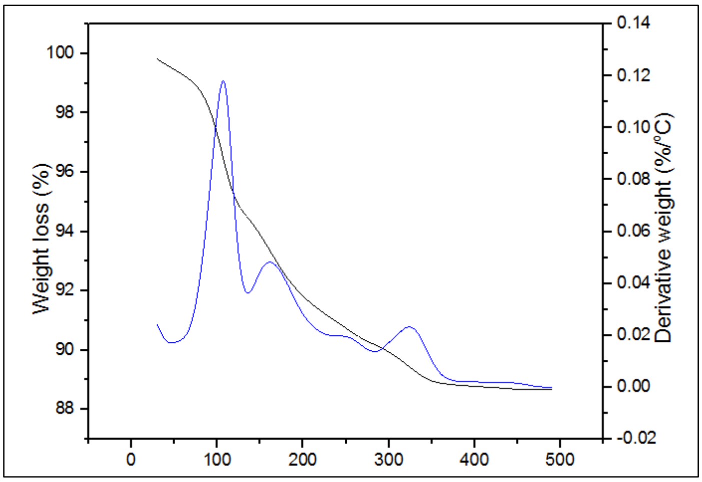

Figure 4 TGA/DSC thermograms of zinc layered hydroxide nitrate –phosphate nanohybrid, ZLNP

Controlled Release Study

The release profiles of nitrate and phosphate anion from ZLH nanomaterial, respectively into soil media solution are shown in Figure 5. The release profile shows two stages of releasing pattern which is a fast release at the early stage followed by a slow sustained release thereafter. The rapid release at the first stage is due to the burst effect caused by the high release of anions that are weakly adsorbed on the external surface of ZLH layered (Berber et al. 2014). Due to the anion exchange capabilities of ZLH, the anion can be released and exchanged with the anion in the release medium. The release of nitrate anion from the nanohybrid into the soil media was higher than the phosphate anion. The result shows that ZLH can be potentially used as a host for plant nutrient sources.

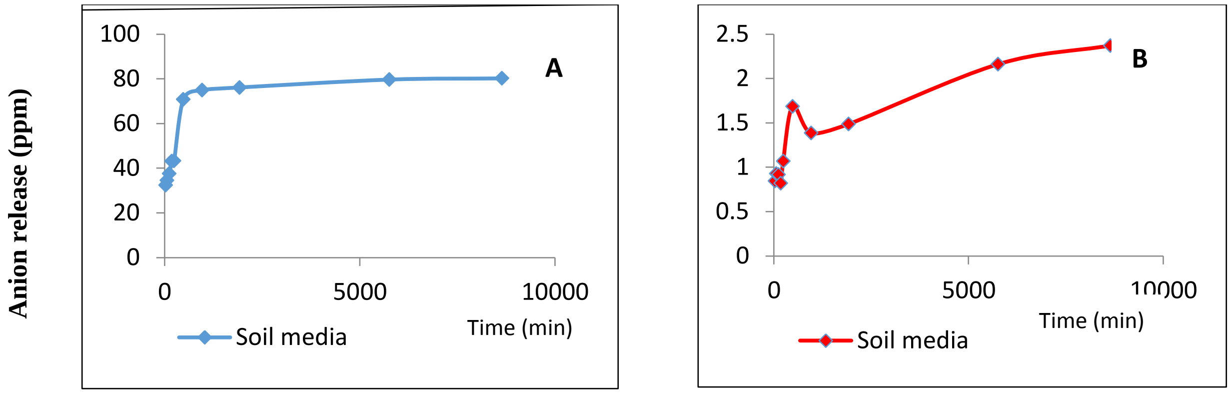

Figure 5 Release patterns of nitrate (A) and phosphate (B) from ZLH into soil solution at various time intervals

Phytotoxicity Test

Phytotoxicity of ZLNP was carried out through seed germination of green bean seeds. Table 1 shows that the percentage of seed germination from ZLNP gives the highest reading compared to commercial fertiliser and its raw material. This indicates that ZLNP is safe for seed germination and non-toxic to plants.

Table 1 Percentage germination of green bean seeds in ZLNP, commercial fertiliser, and raw chemicals

Sample	% Germination
ZLNP	98
Commercial Fertilizer	89
Raw	87

Radical seed length of germinated green beans in ZLNP, commercial fertiliser, raw chemical, and control were also measured. The highest measurement of radical seed length was recorded from ZLNP with an average reading of 22.3 mm as shown in Figure 6. This may be related to zinc content in ZLNP that enhanced radical seed growth.

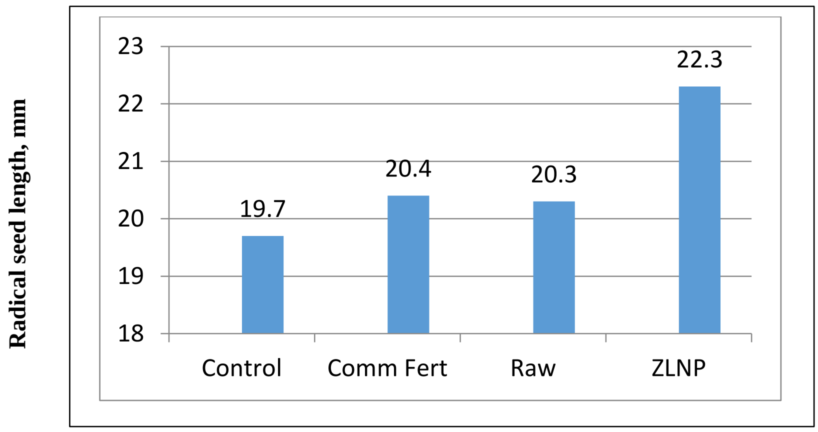

Figure 6 Radical seed length of green beans seeds germinated in water (control), commercial fertiliser, raw material and ZLNP

Plant Growth Study

Figure 7 exhibits the biomass weight of kelempayan seedlings after four months of treatment with ZLNP, commercial fertiliser and raw chemicals. A control study with no chemical treatment was also performed. The short plant growth trial at the nursery shows that treatment with ZLNP recorded the highest biomass yield of kelempayan seedlings compared to other applications.

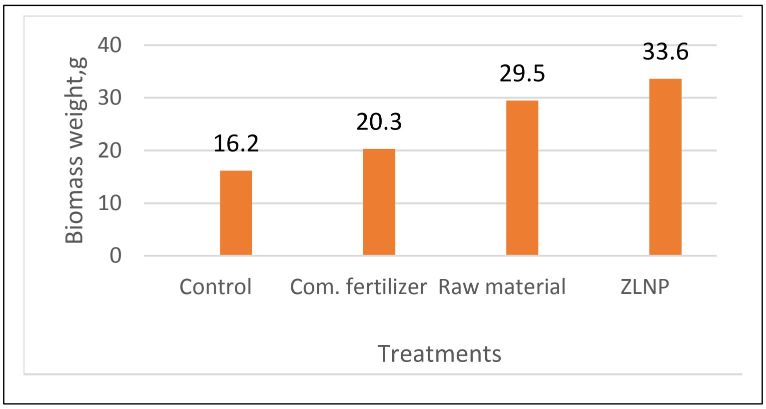

Figure 7 Biomass weight of kelempayan seedlings after four months of application with different treatments

Nitrogen, phosphorus, and zinc uptake in kelempayan seedlings after treatment with various applications are shown in Figure 8, respectively. The concentrations of N, P and Zn in leaf samples from ZLNP treatments had the highest values than control and other treatment. This is tallied with the highest biomass reading observed in similar treatments. This may have contributed to the zinc content and ZLNP-controlled release properties that enhanced the nutrient uptake and increased biomass yield.

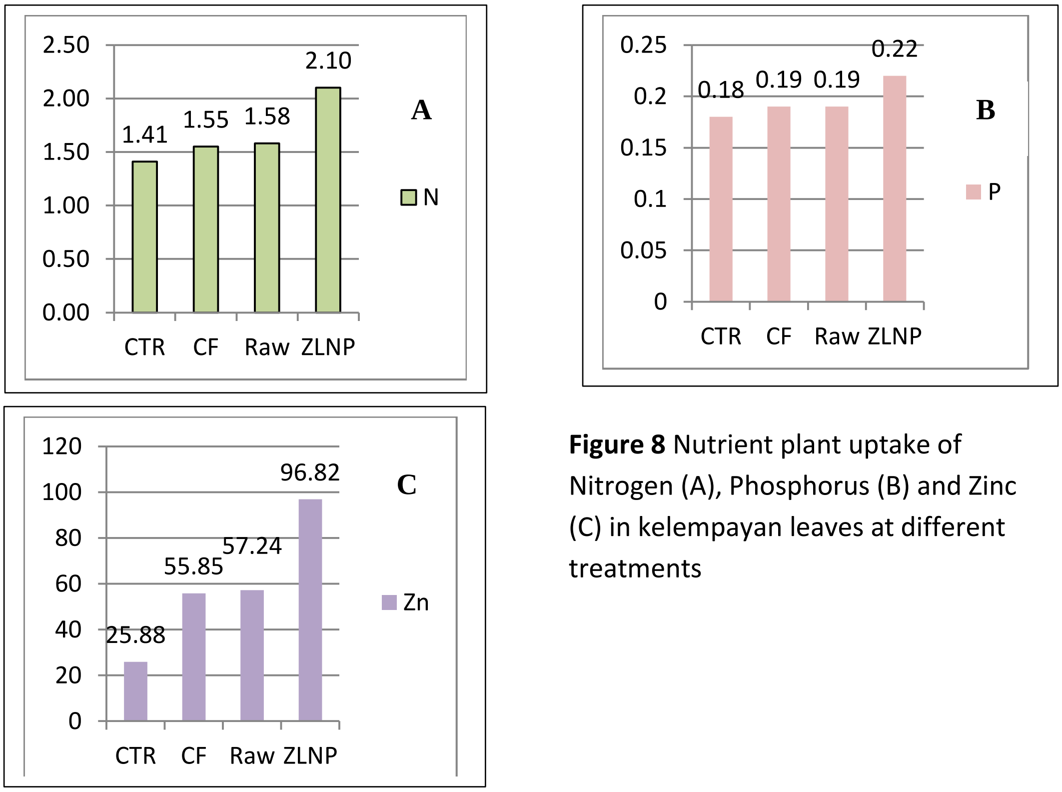

Figure 8 Nutrient plant uptake of Nitrogen (A), Phosphorus (B) and Zinc (C) in kelempayan leaves at different treatments

CONCLUSION

Zinc-layered nitrate and phosphate (ZLNP) nanohybrid was successfully synthesised using the co-precipitation and anion exchange method at a concentration of 3.0 M zinc layered hydroxide nitrate and 0.3 M of potassium hydrogen phosphate. The obtained nanohybrid was thermally more stable than its counterpart and its percentage loading of nitrate and phosphate in the nanohybrid were 20.6% and 12.58%, respectively. The release of nitrate anion from the nanohybrid into the soil media was higher than the phosphate anion. The nursery trial shows that the biomass yield and plant nutrient uptake of kelempayan applied with ZLNP recorded the highest readings compared to treatment with control, commercial fertiliser, and its counterpart (raw). The nanohybrid that recorded the highest seed germination indicates it is non-toxic to plants. The present study shows that ZLH has the potential as a sustained release delivery system for plant nutrient sources.

ACKNOWLEDGEMENT

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PRODUCING THE FORESTRY: PLANT BIOTECHNOLOGY DICTIONARY

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The *Forestry: Plant Biotechnology Dictionary* compiled and described plant biotechnology term resources (English — Malay) that are often used in forestry. A total of 363 term descriptions were recorded and published by the Forest Research Institute of Malaysia (FRIM). The terms can also be found on the Malay Literature Reference Center website at https://prpm.dbp.gov.my/ managed by Dewan Bahasa dan Pustaka (DBP). In terms of field/subfield specialisation, this dictionary covers the scope of *In-vitro* Technology, Plant Cell Biotechnology and Applications, Genetic Markers, Gene Mapping, Bioinformatics, Plant Genetic Engineering, Omics, and the Latest Technologies as well as fundamental terms in Plant Biotechnology. Production of the forestry dictionary began with the signing of a Memorandum of Understanding (MoU) between the Malaysian Forestry Research and Development Board (MFRDB) and DBP on 30 April 2016. A committee specialised in drafting and compiling terms dictionary was then formed. The Forestry: Plant Biotechnology Terminology Committee involved the participation of experts from FRIM, as well as practitioners from industry and higher learning institutes such as Universiti Kebangsaan Malaysia, Universiti Putra Malaysia, and the National Nanotechnology Center. The terms were defined in a simple and concise language specific to the field of Plant Biotechnology to provide the correct Malay terminology for the original English term to students, researchers, and the public.

Keywords: Dictionary, terms, plant biotechnology, forestry

INTRODUCTION

The *Forestry: Plant Biotechnology Dictionary* is a book that compiled and described the term resources (English — Malay) in the field of plant biotechnology, which is often used in forestry. Students and researchers especially faced the problem of obtaining Malay terms in plant biotechnology for already established English terms. Therefore, DBP being the authority on the Malay language and FRIM having the expertise in the fields of forestry and plant biotechnology embarked on producing a suitable dictionary to fulfill the demand. This dictionary covered the scope of *In-vitro* Technology, Plant Cell Biotechnology and Applications, Genetic Markers, Gene Mapping, Bioinformatics, Plant Genetic Engineering, Omics, and the Latest Technologies, as well as fundamental terms in Plant Biotechnology.

Production of the dictionary began with the signing of a Memorandum of Understanding (MoU) between the then Malaysian Forestry Research and Development Board (MFRDB) (now known as Members of the Institute) with DBP on 30 April 2016. A series of discussions were held to explore potential collaboration and determine the financial aspects and terms of reference approval of both parties. The Forestry: Plant Biotechnology Terminology Committee was formed to draft and compile the terminologies. The committee comprised experts from FRIM, as well as practitioners from the industry and higher learning institutes such as Universiti Kebangsaan Malaysia, Universiti Putra Malaysia, and the National Nanotechnology Center.

This dictionary was published to enrich and strengthen knowledge, specifically in the field of Plant Biotechnology. The dictionary can be used as a source of reference for students of higher learning, educators, researchers, practitioners, and other general users to acquire a better explanation of the concepts of selected terminologies.

With terminology definitions and meanings in a simple and concise language, and specific to the field of Plant Biotechnology, this dictionary is hoped to help students, researchers, and the public to get the correct Malay terminology and definition for the original English term.

MATERIALS AND METHODS

The steps and activities involved in the production of the forestry dictionary were as follows:

1. Field selection
2. Preparation of the working paper
3. Appointment of field experts
4. Taxonomic mapping
5. Listing and confirmation of term candidates
6. Preparation and validation of term descriptions
7. Pre-printing
8. Printing
9. Uploading the terms on the Malay Literature Reference Center website at https://prpm.dbp.gov.my/

RESULTS AND DISCUSSION

Two series of steering committee meetings were held on 23 May 2017 and 16 May 2018 to set the financial aspects and terms of reference for the production of the dictionary. Fifteen series of technical committee discussions were held to complete the listing and confirmation of term candidates and the preparation and confirmation of term descriptions. Discussion and finalizing the definitions proved to be a lengthy process, while securing working time from the committee members was difficult, as everyone had commitments and different preferences on discussion dates.

Terminology resources were obtained from the *Biotechnology Dictionary*, a list of terms from the United States Department of Agriculture (USDA), Glossary of Biotechnology and Genetic Engineering by the Food and Agriculture Organization of the United Nations (FAO) (Zaid et al. 1999), Dictionary of Plant Genetics and Molecular Biology (Miglani 1998), *Glossary of Biotechnology and Agrobiotechnology Terms* 5th edition (Nill 2017), and other resources (Choudary & Vijayakumar ; Dood & Robert 1985; Peirik 1997; Glosari Agroteknologi 1997; Kamus Biologi 1983; Kamus Bioteknologi 1999; Kamus Herba 2016; Portal Maya Istilah Sains UKM).

The list of parent terms contained 895 optional terms. The experts have selected 749 unique terms and shortlisted them to 336 terms. The most appropriate match, however, was determined for 163 out of 336 English-Malay terms. After term matching completion, a briefing on the method of the term dictionary compilation was conducted by DBP. Nine series of terminology workshops were then held. The complete list of terminologies was edited by DBP and the final draft was submitted to FRIM on 13 March 2020 for pre- and printing processes.

CONCLUSION

The *Forestry Dictionary: Plant Biotechnology* was published as an authorised and up-to-date reference for terminologies in the field of plant biotechnology that are often used in the field of forestry. This book collects and describes a total of 363 source terms (English — Malay) published by the Forest Research Institute of Malaysia (FRIM) and can be referred to on the Malay Literature Reference Center website at https://prpm.dbp.gov.my/, Dewan Bahasa dan Pustaka (DBP).

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FOREST PRODUCTS

ADHESION AND BONDING PROPERTIES OF ADJACENT LAYERS FROM MIXED TIMBER SPECIES FOR CROSS LAMINATED TIMBER (CLT)

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The adhesion and bonding properties of four different tropical hardwoods, namely batai, sesendok, rubberwood, and kedondong were studied. The anatomical and surface properties of the wood species were determined. Density, surface roughness, and contact angle of wettability were evaluated as their adhesion properties. Three layers of CLT were prepared by applying pressure of 100 and 200 psi and glue spread rates of 200, 250, and 300 g/m^2 single glue line. In terms of bonding properties, block shear and delamination tests were conducted to examine the bonding performance in accordance with BS EN 16351: 2015 standard. Block shear strength (BSS), percent wood failure, and percent delamination of the CLT specimens were evaluated as a function of pressure and glue spread rate. The study shows that batai has the lowest density followed by sesendok, rubberwood, and kedondong. The result also showed the effect of anatomical and surface properties on the adhesion of wood. For bonding properties, the glue spread rate significantly influenced both the shear strength and wood failure percentage of the CLT. The influence of ACQ preservatives on the adhesion and bonding properties of CLT was also studied.

Keywords**:** Adhesion and bonding, mixed timber species, cross laminated timber (CLT), ACQ-treated

INTRODUCTION

Cross Laminated Timber (CLT) is an engineered wood that is already been well received for use in residential, commercial, institutional, and large industrial facilities due to its cost-effectiveness as a building material. First introduced to the market in the early '90s in Germany and Austria, CLT is now beginning to attract interest in the Asian region. Malaysia too has embarked on the study on CLT with the Forest Research Institute Malaysia (FRIM) pioneering CLT-related studies since 2013 (Hamdan et al. 2015). Light-density hardwood Sesendok (*Endospermum malaccense*) was first explored and used in the study. It proceeded with the fabrication of a prototype CLT house and was later recognized by the Malaysian Book of Record (MBOR) in December 2017 as the "First to Use Tropical Timber in Cross Laminated Timber (CLT) Production". Aside from the availability of raw materials, understanding the bonding properties of CLT laminates is very crucial to ensure their integrity and strength as a structural component.

A good adhesive bonding in wood would produce the best quality of laminated and composite wood products. Adhesion properties such as wettability may influence the bonding of the end products (Amorim et al. 2013). Knowing and understanding the anatomical characteristics and physical properties of wood, including the surface roughness, will help in achieving good adhesive bonds (Shi & Gardner 2001). Normally, wood with thicker fibre walls has a higher density and this produces larger contact angles, and consequently, low wettability, which is not good for adhesive bonding (Bao et al. 2016).

Four Malaysian hardwood species were selected based on their density, durability, and availability. The feasibility of manufacturing single and mixed-species CLT from Malaysian hardwood treated with Alkaline Copper Quaternary (ACQ) preservative is important. This study aims to determine the basic properties, investigate and compare the adhesion and bonding properties of CLT made from different Malaysian hardwood species- mono and mixed- and evaluate the influence of ACQ preservatives used on the CLT.

MATERIALS AND METHODS

Raw Material

Four selected timber species namely batai (*Paraserianthes falcataria*), sesendok (*Endospermum malaccense*), rubberwood (*Hevea brasiliensis*), and kedondong (*Burceraceae sp.*) are obtained from a commercial wood sawmill. The protocol to fabricate the CLT panel is described in Hamdan et al. (2017). The wood was kiln-dried until it reached about 12 % moisture content and machined to the required sizes according to the standards.

Methods

The anatomical and surface properties of the wood species were determined. Density, surface roughness, and contact angle of wettability were evaluated as to their adhesion properties. Three layers of CLT were prepared by applying pressure of 100 and 200 psi and glue spread rates of 200, 250, and 300 g/m^2 single glue line. In terms of bonding properties, block shear and delamination tests were conducted to examine the bonding performance in accordance with BS EN 16351: 2015 standard. Block shear strength (BSS), percent wood failure, and percent delamination of the CLT specimens were evaluated as functions of pressure and glue spread rate. The feasibility of manufacturing mixed-species cross-laminated timber (CLT) treated with Alkaline Copper Quaternary (ACQ) preservative was evaluated and its effect on the adhesion and bonding properties of CLT was also studied. The samples were cut and planned prior to treatment. One-way analysis of variance (ANOVA) and Least Significant Difference (LSD) tests were conducted to evaluate the effects of preservative retention and species on surface roughness, the contact angle of wettability, block shear strength (BSS), and delamination.

RESULTS AND DISCUSSION

The densities of the timber batai, sesendok, rubberwood, and kedondong are 220 kg/m^3, 500 kg/m^3, 590 kg/m^3, and 620 kg/m^3 respectively. The study shows that batai has the lowest density followed by sesendok, rubberwood, and kedondong. The surface roughness study indicates that kedondong had the smoothest surface with an average roughness value of 4.03 (µm) while batai had the roughest surface with an average roughness value of 8.88 µm followed by sesendok (6.61 µm). Rubberwood and kedondong had similar average roughness values. Contact angles were significantly different between the timber species except for batai and sesendok (Figure 5). Contact angle decreased as a function of time. The contact angles for batai, sesendok, kedondong, and rubberwood were 32.25°, 36.12°, 47.77°, and 42.92° respectively. The contact angle for batai decreased from 32.25° to 0° within 7 min, much faster than the rest of the species (Alia et al. 2019). The result also showed the effect of anatomical and surface properties with the adhesion of wood. For bonding properties, the glue spread rate significantly influenced both the shear strength and wood failure percentage of the CLT. Clamping pressure, on the other hand, did not affect the bonding properties of the CLT despite having different ranges of wood density. The delamination behaviour of the samples also was not influenced by both clamping pressure and glue spread rate.

Nur Amira et al. (2020) reported that after treatment with ACQ, batai has the highest density increment (15.76 %) followed by sesendok (2.4 %), rubberwood (2.2 %), and kedondong (0.88 %). Besides, an increment in the roughness value of batai (10.81%), sesendok (21.42%), rubberwood (39.22%), and kedondong (48.29%) was also observed. A significant difference was found in the contact angle of wettability for each species after treatment. High wettability was observed especially from rubberwood as the contact angle value was reduced by as much as 54.5 %, which gives the lowest contact angle value among the species. Regardless of ACQ retention, the surface roughness of ACQ-treated samples significantly lowered the BSS of each species at a lower glue spread rate (200 g/m^2 and 250 g/m^2) and pressure (0.7 N/mm^2) compared to the untreated control except for ACQ-treated rubberwood.

Meanwhile, at a higher glue spread rate (300 g/m^2), stronger BSS was found compared to the untreated control sample except for ACQ-treated kedondong. For single-species CLT, ACQ-treated rubberwood has the highest BSS followed by kedondong, sesendok, and batai with values of 9.53 N/mm^2, 6.00 N/mm^2, 5.68 N/mm^2, and 4.19 N/mm^2 respectively at optimum parameters. While for mixed-species CLT, the combination of ACQ-treated rubberwood-sesendok-rubberwood has the highest BSS with a value of 8.05 N/mm^2. The average wood failure percentage (WFP) for each CLT configuration in this study ranged from 75 % to 100 %. No delamination was found in all the CLT samples tested. Among the species studied, rubberwood exhibited the best bonding performance for both untreated control and ACQ-treated samples followed by kedondong, sesendok, and batai. These combined data suggest that under the conditions tested, ACQ provided better bonding performance overall than the untreated control group at optimum parameters.

CONCLUSION

Contact angle had a strong relationship between anatomical characteristics and surface wettability. The wettability of batai was highly influenced by fibre wall thickness and lumen diameter while sesendok was influenced by fibre diameter, fibre length, and lumen diameter. For kedondong, wettability was influenced by fibre diameter, fibre length, and fibre wall thickness. Fibre length and lumen diameter affected the wettability of rubberwood significantly. With optimum glue spread and pressure, ACQ-treated timber enhances the bonding performance better than control.

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SORPTION KINETICS OF WOOD REINFORCED WITH PHENOLIC RESIN

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Batai (*Paraserianthes falcataria*) and kedondong (*Canarium spp.*) wood were modified with low molecular weight phenol formaldehyde (LMwPF) resin in order to reduce its hygroscopicity. Batai and kedondong were impregnated with LMwPF resin, followed by curing at a high temperature. The surface wettability, physico-mechanical properties, and sorption isotherm of the untreated and treated wood were investigated. The surface wettability of the modified wood was reduced as a result of the treatment. Thickness swelling and water absorption of the modified batai and kedondong reduced while positive anti-swelling efficiency increased. However, there was no significant difference observed for mechanical properties between untreated and treated kedondong. The equilibrium moisture content (EMC) of untreated batai and kedondong was higher than impregnated samples. For example, at 95% RH, untreated kedondong showed an EMC of 19.10% whereas the treated sample was 17.12%. Furthermore, the hysteresis loop of the untreated sample results was slightly higher than the treated sample. The results indicate that the treatment reduces the hygroscopicity of batai and kedondong.

Keywords**:** Impregnation modification, resin, wood enhancement

INTRODUCTION

Hardwood timbers are categorised into three classes which are low, medium and heavy density hardwoods that served a variety of applications and performances. Focusing on outdoor applications, heavy hardwood timber is commonly used due to its excellent performance in strength, durability, and resistance to bio-deterioration agents compared to light and medium hardwood species. However, heavy hardwood species, such as chengal, are limited and the price is expensive. Wood is a hygroscopic material that tends to absorb surrounding moisture and lead to decay. In order to address the shortage of timber supply, low density timber such as batai, kelempayan, mahang, and several other species could become a potential alternative supply of raw materials for wood-based industries (Hashim et al. 2015). The species are very fast growing; however, these species have disadvantages such as low dimensional instability, inferior mechanical strength, and low durability (Ratnasingam et al. 2020). To enhance the value and utilization of this species, the properties of the wood can be improved by wood modification. According to Hill (2006), the chemical modification includes bulking, internal coating, and crosslinking resulting in enhancing properties of low density hardwoods. The wood modification could either affect the chemical nature of the material or not. In this study, impregnation modification was selected based on successful results from previous studies that demonstrate enhancement in the wood properties.

MATERIALS AND METHODS

Defect-free batai (*Paraserianthes falcataria*) and kedondong (*Canarium* spp.) were selected in this study. Low molecular weight phenol formaldehyde (LMwPF) resin was used to impregnate the wood samples. The wood samples were placed into a treatment cylinder. The impregnation process was started by applying a vacuum followed by filling resin solution. Then, additional pressure was applied. Finally, the treated samples were put in the oven to fully cure the resin in the wood samples.

The dimensional stability of untreated and treated samples was evaluated according to the previous study by Anwar et al (2019). Meanwhile, the mechanical properties testing were conducted based on British Standard BS 373:1957 (BSI 1957). The sorption isotherm of the untreated and treated sample was determined using DVS Intrinsic apparatus (Surface Measurement Systems, London, UK). The untreated sample was used for comparison.

RESULTS AND DISCUSSION

The optimum concentration of LMwPF for the treatment of batai wood was determined. It was found that the WPG of treated batai ranged from 17 to 20%, while the WPG for kedondong ranged from 6.5 to 15%. The increment in WPG was depending on the concentration used. Moreover, both the physical and mechanical properties of the treated batai and kedondong were significantly improved (Table1).

Table 1 The dimensional stability and static bending of untreated and treated samples

		Dimensional stability (%)				Mechanical Properties (Nmm^{-2})	
Species	**PF conc. (%)**	**WA**	**TS**	**SC**	**ASE**	**MOR**	**MOE**
Kedondong	Untreated	42.80[a] (11.48)	3.30[a] (0.56)	6.94[a] (0.37)	N/A	78[a] (5.94)	8015[a] (480)
	30%	18.90[b] (5.50)	2.29[b] (0.41)	4.74[c] (0.57)	31.50 (8.24)	84[a] (15.15)	8763[a] (1405)
Batai	Untreated	29.91[a] (8.55)	3.66[a] (1.23)	7.82[a] (0.79)	N/A	49[a] (9.61)	2929[a] (1023)
	30%	16.60[b] (3.15)	2.08[b] (0.55)	4.60[b] (0.58)	41.22 (7.45)	50[a] (8.79)	3789[a] (571)

Note: Group means with the same letter are not significantly difference at $p \leq 0.05$
Numbers in parenthesis are standard deviation

Figure 1 shows the sorption isotherm of untreated and phenolic-treated batai and kedondong wood. The results prove that the presence of LMwPF resin in the wood cell can reduce the value of equilibrium moisture content (EMC) as the relative humidity (RH) increased. Sorption isotherm properties of the batai and kedondong wood modified with LMwPF resin are mainly influenced by cell wall bulking which limited further swelling by water (Figure 2).

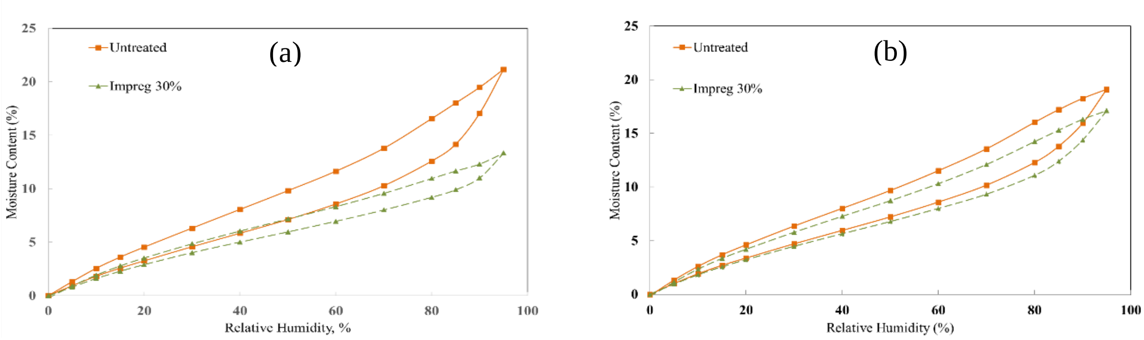
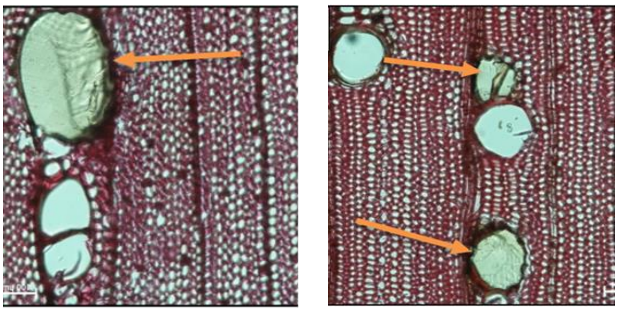


Figure 1 Sorption isotherm curve of untreated and impregnated a) batai and b) kedondong at 30% LMwPF resin concentration



batai kedondong

Figure 2 Microscope images of impregnated batai and kedondong where the vessel appear light orange (arrow) shows the deposited resin at 30% concentration (cross section)

CONCLUSION

In conclusion, the dimensional stability, and mechanical properties of the selected wood species in this study were improved after being impregnated with LMwPF. The analysis on sorption isotherm has proven that the polymer loading in the wood cell has affected the sorption behaviour at below 95% RH. Thus, it was found that this impregnation technique was suitable to enhance the dimensional stability of wood.

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FIBRE BONDING INTERACTION ON RECYCLED PULP AND VIRGIN BAMBOO PULP

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Paper recycling is an important practice in the protection of our environment. In paper recycling, the paper mechanical property becomes weak after each time being recycled due to its loss in fibre bonding interaction. Recycled paper needs to be added with virgin pulp to maintain its strength. Currently, most of the virgin pulp used by Malaysian paper mills is imported softwood pulp. This imported softwood pulp can be substituted with bamboo pulp since the bamboo fibre properties are comparable to softwood fibre. Bamboo is one of the materials included under the National Timber Industry Policy (NATIP) launched in 2009 and supports the Malaysia Timber Industry Board (MTIB) project under Malaysia Bamboo Industry Development Action Plan (2011-2020). This project aims to evaluate the potential of virgin bamboo pulp in maintaining recycled pulp strength. Bamboo species of *Bambusa vulgaris, Gigantochloa levis*, and *Gigantochloa scortechinii* (buluh aur, buluh beting, and buluh semantan, respectively), and each species have 3 different ages of 1, 3, and 5 years old were analysed, their pulp and paper properties were determined and then mixed with recycled pulp. It was found that different species of bamboo have different properties in terms of fibre morphology. Fibre diameter, fibre length, and cell wall thickness increase with the increase of the bamboo age, but the lumen diameter decreased when the bamboo gets older. Pulping yield ranged from 35.7 to 51.7% for different bamboo species and ages. The paper mechanical properties for burst index, tear index, tensile index, and folding endurance ranged from 1.32 to 2.36 kPa.m^2/g, 7.48 to 14.9 Nm^2/g, 16.02 to 29.68 Nm/g, and 2 to 28 double folds, respectively, of different bamboo species and ages. The recycled paper strength was improved by combining it with bamboo fibres. The mechanical strength increased proportionally to the amount of bamboo pulp added. The addition of 2.5 % bamboo pulp to the recycling pulp has already improved all the paper's mechanical properties. Paper’s mechanical properties are affected by the fibre bonding interaction of pulp. Bamboo has promising potential as the raw material for pulp and paper as well as in enhancing the mechanical properties of recycled paper.

Keywords: Fibre bonding interaction, bamboo pulp, recycle pulp, pulp and paper

INTRODUCTION

Recycling of various materials has come under the increasing spotlight as the environmental awareness of the public increases. Recycling is associated with a clean green image and industries are under pressure more than ever before to perform in this area. Pulp and paper manufacturing is no exception to this recycling trend. In paper recycling, the fibre bonding interaction becomes weak each time being recycled (Xuan & Lars 2020). Recycled paper needs to be added with virgin pulp to maintain its strength. Currently, in Malaysia, most of the virgin pulp used is imported softwood pulp. This imported softwood pulp can be substituted with bamboo pulp since the bamboo fibre properties are comparable to softwood fibre (de Assis et al. 2018). Bamboo is one of the materials included under the National Timber Industry Policy (NATIP) launched in 2009 and supports the Malaysia Timber Industry Board (MTIB) project under Malaysia Bamboo Industry Development Action Plan (2011-2020). The aim of this project was to evaluate the potential of virgin bamboo pulp in maintaining recycled pulp strength.

MATERIALS AND METHODS

A comparison among bamboo species is important to understand which species are most suitable for pulp and paper material. It is also important to know at what age bamboo is matured enough to be the main material for paper making. Bamboo species of *Bambusa Vulgaris, Gigantochloa levis,* and *Gigantochloa scortechinii* (buluh aur, buluh beting, and buluh semantan, respectively), and each species have 3 different ages of 1, 3, and 5 years old were analysed, their pulp and paper properties were determined and then mixed with recycled pulp.

All the bamboo samples were collected at the Forest Research Institute Malaysia (FRIM), Kepong campus. Fibre morphology can indicate the quality of pulp production. Fibre morphology was determined by using the Franklin method as stated by Hemmasi et al. (2011).

Pulping's main goal is to isolate the fibres from one another. Soda-Anthraquinone (AQ) pulping was used to digest the bamboo into pulp. The pulping parameters used for the pulping were 20% of NaOH, 170^{o}C pulping temperature, 90 min to reach pulping temperature and 90 min at pulping temperature, 1:6 bamboo to liquor ratio, and 0.1% of AQ. The recycled pulp was reslushed by using the hydro pulper for 20 minutes. Laboratory paper was made by blending the bamboo pulps with recycled pulp at ratios of 2.5%, 5.0%, 7.5%, and 10%.

TAPPI standard T 205 (TAPPI, 1994) was used to conduct the papermaking process. The physical and mechanical properties of paper were tested according to TAPPI standard methods T 220 (TAPPI 1994).

RESULTS AND DISCUSSION

Fibre Morphology

Table 1 shows the morphological characteristic of bamboo for each species. The result showed that the fiber length increased with an increase of age or as it gets older i.e., 1 to 5-year-old this trend applies to all species of bamboo. The highest-fibre length was *G. scortechinii* with a fibre length of 4.00 mm at the age of 5 years. The shortest fibre length was in *B. vulgaris*, which was 2.98 mm at the age of 1 year. This indicates that the increase in age gives longer fibre and thus the stronger the paper will be produced.

Table 1 Morphological characteristics of bamboo

Species	Characteristics	Age		
		1 year	**3 years**	**5 years**
Bambusa vulgaris	Fibre Length (mm)	2.98	3.07	3.12
(buluh aur)	Fibre Diameter (µm)	12.61	12.87	14.40
	Lumen Diameter (µm)	6.28	5.80	5.61
	Cell Wall Thickness (µm)	3.16	3.53	4.40
Gigantochloa levis	Fibre Length (mm)	3.09	3.27	3.47
(buluh beting)	Fibre Diameter (µm)	14.38	14.42	18.71
	Lumen Diameter (µm)	8.96	8.95	7.68
	Cell Wall Thickness (µm)	2.71	2.73	5.52
Gigantochloa scortechinii	Fibre Length (mm)	3.35	3.75	4.00
(buluh semantan)	Fibre Diameter (µm)	13.90	15.35	17.05
	Lumen Diameter (µm)	7.22	7.16	5.27
	Cell Wall Thickness (µm)	3.34	4.10	5.89

To predict the suitability to produce quality pulp for papermaking, the Runkel ratio needs to be calculated. It can be determined by the ratio of the cell wall to lumen diameter, and the Runkel ratio must be less than 1 to be a good material for pulp and paper application. Table 2 shows the Runkel ratio for each species at a different age. A Higher Runkel ratio will produce bulkier paper because the fibre was stiff and less flexible thus producing poor bonding ability compared to the lower Runkel ratio (Sadiku & Abdukareem 2019). *G. levis* has the best Runkel ratio.

Table 2 Runkel ratio for each species at a different age

Species	Age		
	1 year	**3 years**	**5 years**
Bambusa vulgaris	1.14	1.32	1.65
Gigantochloa levis	0.63	0.66	1.50
Gigantochloa scortechinii	0.99	1.27	2.55

Bamboo's Pulp Yields

Figure 1 displays a comparison of bamboo pulp yield between species and ages. *Gigantochloa scortechinii* for 1-year-old has the highest total yield (51.7%), whereas *G. levis* of 3 years old has the lowest. Overall, *G. scortechinii* has the highest total yield compared to *B. vulgaris* and *G. levis*.

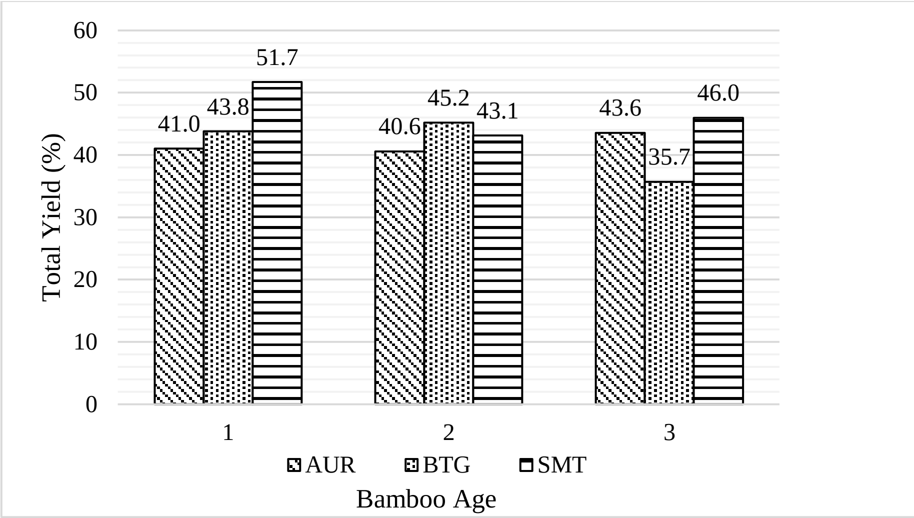

Figure 1 Bamboo pulp total yield at different ages

Bamboo Paper Properties

Mechanical properties of paper are important to distinguish whether the material is suitable for pulp and paper along with the durability for the material to withstand any wear, pressure, or damage. Paper's mechanical properties are affected by the fibre bonding interaction of pulp (Hanna 2007). Table 3 exhibits the mechanical properties of bamboo paper. It was found that *G. levis* has the highest mechanical properties compared to *B. vulgaris* and *G. scortechinii*.

Table 3 Mechanical properties of bamboo paper

Specific properties	unit	Paper sample		
		Bambusa vulgaris	*Gigantochloa levis*	*Gigantochloa scortechinii*
Grammage	g/m^2	61.976	61.548	62.806
Thickness	mm	0.70	0.56	0.69
Burst index	$kPa.m^2/g$	1.437	2.364	1.323
Tear index	Nm^2/g	9.02	14.899	7.48
Tensile index	Nm/g	18.798	29.684	16.018
Fold endurance	Double folds	3	28	2

Mixing Recycled Pulp

Table 4 shows the effect of adding bamboo pulps to a recycled pulp on paper properties. The recycled pulp strength was improved by combining it with bamboo fibres. The addition of 2.5 % bamboo pulp to the recycling pulp has already improved all the paper's mechanical properties.

Table 4 The effect of mixing bamboo pulp with recycled pulp on paper properties

Sample (Percentage bamboo pulp added)	Grammage (g/m^2)	Burst Index ($kPa.m^2/g$)	Folding Endurance (double folds)	Tearing Index ($mN.m^2/g$)	Tensile Index (Nm/g)
Recycled pulp	59.35	2.27	7	5.98	24.86
Bambusa vulgaris					
2.5%	54.90	2.42	7	6.96	27.56
5%	56.25	2.62	12	6.92	29.44
7.5%	56.05	2.82	14	7.35	33.28
10%	56.61	2.87	15	7.98	32.03
Gigantochloa levis					
2.5%	54.83	2.54	9	7.03	30.07
5%	54.96	2.72	11	7.30	30.73
7.5%	55.98	2.77	13	7.66	31.10
10%	55.86	2.81	15	7.88	32.40
Gigantochloa scortechinii					
2.5%	56.39	2.47	9	7.27	27.47
5%	55.82	2.74	11	7.36	30.99
7.5%	56.20	2.80	12	7.46	32.01
10%	56.98	3.17	14	8.27	32.08

All species give a positive impact on the increment of recycling paper mechanical properties; it shows that as the percentage is increased, the mechanical properties increase as well. The increase of interfibre bonding will lead to increasing the mechanical properties of recycling paper.

CONCLUSION

It was found that different species of bamboo have different properties in terms of fibre morphology. Fibre diameter, fibre length, and cell wall thickness increase with the increase of the bamboo age, but the lumen diameter decreased when the bamboo gets older. Pulping yield ranged from 35.7 to 51.7% for different bamboo species and ages. The paper mechanical properties for burst index, tear index, tensile index, and folding endurance ranged from 1.32 to 2.36 $kPa.m^2/g$, 7.48 to 14.9 Nm^2/g, 16.02 to 29.68 Nm/g, and 2 to 28 double folds, respectively, of different bamboo species and ages. The mechanical strength increased proportionally to the amount of bamboo pulp added to the recycled pulp. Therefore, when the percentage of bamboo fibre was added, the mechanical strength was increased due to the fibre bonding interaction of pulp. Bamboo has promising potential as the raw material for pulp and paper as well as in enhancing the mechanical properties of recycled paper.

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DEVELOPMENT OF TRANSPARENT AND FLEXIBLE NANOFIBRILLATED CELLULOSE THIN FILM FROM LOCAL FOREST SPECIES AS A GREEN SUBSTRATE FOR POTENTIAL ELECTRONIC APPLICATION

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Nanocellulose receives huge attention for various applications owing to its abundance, renewability, biodegradability, and interesting attributes. The increased interest is also due to the environmental and sustainable impact that nanocellulose can offer over non-renewable materials such as plastic. Most electronic devices available today are fabricated from non-renewable materials. Therefore, research on sustainable electronics using nanocellulose is timely in response to disposal issues that linger around non-renewable electronic devices today. Nanocellulose could play an active and inactive role in electronic devices such that it could be converted into flexible and transparent film with good mechanical properties and low coefficient thermal expansion. Therefore, this special type of thin film made from renewable feedstocks could become the next generation of the substrate for the production of sustainable, transparent, and flexible electronics**.** The objective of this project was to convert pioneer forest species i.e *Macaranga gigantea* into nanofibrillated cellulose followed by the fabrication of thin films. Subsequently, the thin film was deposited with a conductive material as a precursor towards the fabrication of electronic devices. The conversion of forest resources into this type of intermediate product will revolutionize local traditional forest products into high-value materials. This also paves the way toward the promotion and creation of sustainable products from the abundant source of cellulose available locally.

Keywords: Nanocellulose, electronics, sustainable, thin film

INTRODUCTION

There is a pressing need to develop sustainable products from renewable resources in order to address the current issue of climate change, resource depletion, and disposal issue. Cellulose, being the most abundant source worldwide, is an excellent candidate for the creation of sustainable products for various applications.

Due to the abundance of cellulose sources globally, research on nanocellulose production is mostly conducted on lignocellulosic materials. However, nanocellulose can also be produced from marine animals such as tunicate, algae, and bacteria. There are essentially three types of nanocellulose namely nanofibrillated cellulose, nanocrystalline cellulose, and bacterial cellulose. Nanofibrillated cellulose (NFC) is prepared via mechanical processes such as microfluidizing, homogenizing, grinding, or ultrasonication (Thomas et al. 2018) and usually in combination with chemical or enzymatic pre-treatment. NFC usually possesses length in a few micrometres, whereas width is between 2-60 nm (Hoeng et al. 2016). After conversion to a thin film, NFC could exhibit its film transparency up to 90% at 600 nm (Fukuzumi 2008); the value of which is comparable to plastic material. On the other hand, nanocrystalline cellulose (NCC) is commonly isolated by treating pristine cellulose with a mineral acid such as sulphuric acid. The hydrolysis readily removes the amorphous region in cellulose while leaving the crystalline region intact. As a result, the resulting NCC has dimensions between 10-50 nm in width and 100-500 nm in length depending on the source and hydrolysis conditions used (Bras et al. 2011). NCC is also used as a substrate for electronics in some of the reported works, but the majority of related research focused on NFC. The reason for this could be attributed to the higher stiffness of NCC in comparison to NFC (Li & Lee 2017).

Looking into the electronics sector, most products commercially available are made from non-renewable materials such as the use of silicon or metallic oxide. There are many works conducted on the use of nanocellulose as a substrate for flexible and transparent electronics (Li & Lee 2017; Nogi et al. 2015). The increased interest is due to nanocellulose having good mechanical properties, flexibility, and transparency; the properties are much needed to fabricate sustainable, transparent, and flexible electronics. Various works have been carried out to confer conductivity on nanofibrillated cellulose films with techniques such as printing, mixing, and coating using conductive materials namely carbon nanotubes (Zhu et al. 2013; Zheng et al. 2013; Salajkova 2013), graphene oxide, silver nanowires, polypyrrole and poly(3,4ethylenedioxythiophen)-poly(styrenesulfonate) (PEDOT: PSS) (Valtakari et al. 2015) and nanocellulose have been reported.

The objectives of this project were to optimize the process of fibrillation to obtain high yield NFC from *Macaranga gigantea* (locally known as mahang gajah) and subsequently to produce transparent and flexible NFC thin film and finally to incorporate conductive material onto the thin film and evaluate the conductive thin film performance.

MATERIALS AND METHODS

Primary Processing

Logs of *Macaranga gigantea* obtained from the FRIM campus were chipped and subsequently screened to produce wood chips of suitable dimensions for pulping.

Pulping and Bleaching

Kraft pulping was conducted on *Macaranga gigantea* wood chips to produce unbleached pulp. Subsequently, the pulp was bleached via a 5-stage bleaching sequence. Bleached pulp was then used as a feedstock for the optimisation study of NFC.

Pre-Treatment and Mechanical Fibrillation

Optimisation was carried out by introducing bleached pulp to the pre-treatment process via enzymatic process and chemical using TEMPO (2,2,6,6-tetramethylpiperidine-1-oxyl)-mediated oxidation process. Subsequently, the fibrillation process was focused on using homogenisation and sonication methods at selected durations and varying amplitudes (for sonication). The morphology of the resulting NFC was observed under Atomic Force Microscopy (AFM). The NFC was also characterised for its crystallinity using X-ray Diffraction (XRD) technique.

Fabrication of Thin Film and Deposition of Conductive Material

Fabrication of thin film from NFC suspension was conducted using the filtration technique or casting method. Subsequently, the thin film was used as a substrate for the fabrication of conductive thin film. The silver nanowire was used as a conductive material in which incorporation of nanosilver wire onto thin was achieved by a dip coating method. The effect of time and concentration on the conductivity of the thin film was studied. The conductivity of the thin film was assessed using a four-point probe measurement. The conductive thin film was also observed under Scanning Electron Microscopy (SEM) to study its surface morphology.

RESULTS AND DISCUSSION

Preparation of NFC from *Macaranga gigantea* was studied at various parameters that involved pre-treatment study via enzymatic process and chemical using TEMPO (tetramethylpiperidine-oxyl)-mediated oxidation process. The fibrillation process was focused on homogenization and sonication methods at selected durations and varying amplitudes (for sonication). Figure 1 shows the NFC produced from mahang gajah and its corresponding AFM images. AFM was used as the main analytical tool to verify the nanoscale dimension of the resultant NFC. From this project, the process condition to produce NFC was optimized via enzymatic pre-treatment followed by sonication at 40% amplitude for 30 minutes. Figure 2 shows the XRD diffractogram of the NFC. XRD analysis is essential to evaluate the crystallinity of the NFC prepared. The nanofibrillated cellulose produced at this condition gives 91% yield with an average width of 17 nm and 79% crystallinity.

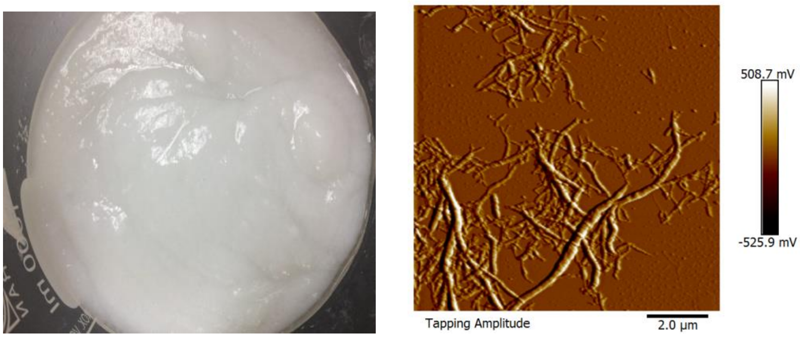

Figure 1 NFC produced from *Macaranga gigantea* (left) and AFM image of NFC (right)

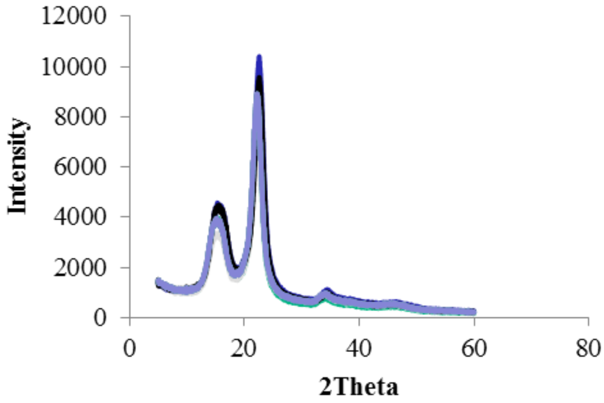

Figure 2 XRD diffractogram of NFC produced via enzymatic pre-treatment

Transparent and flexible NFC thin film was achieved by fabricating thin film via casting and filtration techniques. It was demonstrated that thin film can be fabricated from NFC with appropriate transparency. Properties such as thermal stability, porosity, and wettability (contact angle) showed similar values for both *Macaranga gigantea* and commercial NFC. The tensile strength of the thin film ranged from 25.2–50.2 MPa. Figure 3 shows the thin film produced from the NFC of *Macaranga gigantea.*

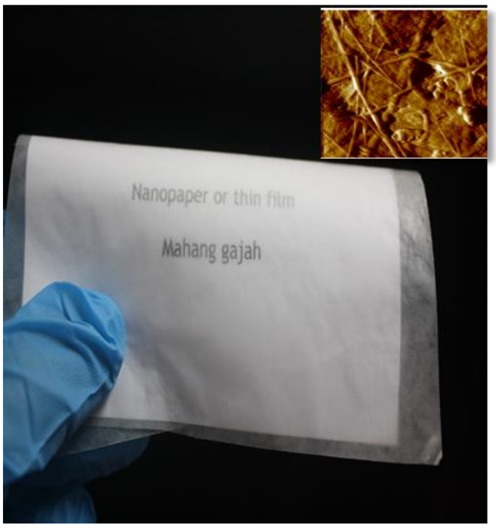

Figure 3 Thin film produced from NFC of *Macaranga gigantea*. Inset shows the corresponding AFM of the thin film

The thin film was made conductive by the introduction of silver nanowire onto its surface via dip coating technique at varying times and silver nanowire concentrations. The highest conductivity was observed when coating time was conducted for 2 hours at 0.5 wt% concentration. Figure 4 displays the conductive thin film produced from NFC with the deposition of silver nanowire and its surface morphology observed under SEM.

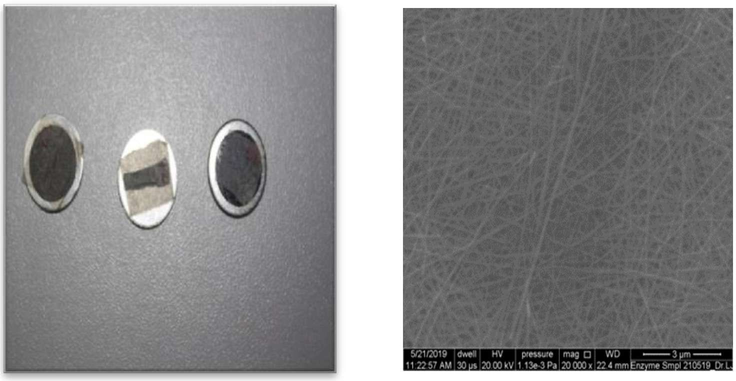

Figure 4 Conductive thin film by deposition of silver nanowire (left) and SEM image of the conductive thin film (right)

CONCLUSION

In this project, conversion of *Macaranga gigantea* into nanofibrillated cellulose at varying process parameters was successfully conducted. The preparation of nanofibrillated cellulose was optimized via enzymatic pre-treatment followed by sonication at 40% amplitude for 30 minutes, which gave 91% yield with an average width of 17 nm and 79% crystallinity. Nanofibrillated cellulose was then converted into thin films in which conductive material was deposited via the dip coating method at varying times and concentrations. The successful fabrication of conductive thin film was evaluated by its conductivity value.

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INSECTICIDAL ACTIVITY OF NANOENCAPSULATED ROTENONE TO POWDERPOST BEETLES

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Powderpost beetle is a serious pest of seasoned sawn timbers. Protective measures against powderpost beetle infestation include applying insecticides that act as a toxicant or deterrent. Yet, such a method is prone to chemicals leaching that might reduce their protective efficacy with possible contamination to the environment. One possible technique to reduce the leaching process is by encapsulation of the insecticides into nano-sized polymer shells. In this study, the insecticidal activities of nanoencapsulated rotenone to powderpost beetles using rubberwood as the substrate were investigated. Five (5) adults of *Minthea reticulata* (Coleoptera: Bostrichidae: Lyctinae) were introduced into a glass bottle containing a rubberwood block (50 x 25 x 15 mm) dipped with either various concentrations of nanoencapsulated rotenone (1-25 w/w%), commercially available biocides or solvent as a control. Five (5) replicates were conducted for each treatment. After 14 days, an evaluation was made by calculating the mortality rate, visual rating assessment, and mass loss due to infestation. Results were compared to untreated rubberwood to ensure healthy and vigor powderpost beetles were used for this study. Our results indicate the possible application of nanoencapsulated rotenone as an alternative for environmentally-friendly wood protection against powderpost beetles.

Keywords: Insecticides, nanoencapsulation, powderpost beetle, rubberwood

INTRODUCTION

Wood is widely used as raw material for buildings, furniture, and other wood-based products due to its versatility, strength-to-weight properties, and durability to withstand degradation. However, certain wood species are vulnerable to insect attack and decay due to the low protective chemicals (e.g. extractives) and high carbohydrate content (e.g. sugar and starch) that is attractive to fungi and insects such as wood borers (Zabel & Morrell 1992). Destruction of timber and timber-based products by insects and fungi is massive and estimated at USD 1 billion and USD 300 billion, respectively (Clausen & Yang 2007; Ghaly & Edwards 2011).

Applying wood preservatives may increase the durability and lengthen the wood service life. Commercially available preservatives such as the plant-derived rotenone have been proven to be effective against pest management including insects (Isman 2020; Zeng et al. 2001). Despite being more environmentally-friendly preservatives compared to conventional preservatives, the application is limited as it is easily degraded by light and temperature, as well as solubility with solvents which significantly reduces its efficacy (Cheng et al. 1972). One of the alternatives to overcome the problem is by applying protective layers, such as encapsulation of the biocides into a polymer shell.

In this study, the efficacy of nanoencapsulated rotenone was tested against the powderpost beetle, *Minthea reticulata*. Rubberwood (*Hevea brasiliensis*) was selected as the test substrate as it is one of the most important raw materials for timber and timber-based products and is highly susceptible to fungi and wood borers attack (Ho 1999; Teoh et al. 2011). Conventional treatments using boron and copper chromium arsenic (CCA) are becoming less popular and restricted due to health and environmental concerns (Hingston et al. 2001). Therefore, alternatives to safer preservatives and optimizing their application are required. Preliminary results of encapsulated rotenone efficacy for protection against wood borers were presented and briefly discussed in this paper.

MATERIALS AND METHODS

Preparation of Rotenone Nanocapsule

Rotenone (Sigma-Aldrich) was fabricated with poly (styrene maleic anhydrate) (PSMA) as the polymer shell, poly (vinyl acetate) as an adjuvant, and hydroxypropyl cellulose acted as a surfactant. Nano-size poly was then prepared through miniemulsion in-situ polymerization techniques. The rotenones-PSMA-hydroxypropyl cellulose-PVA and water mixtures were homogenized using high speed homogeniser at the stirring rate of 4000 rpm for 30 minutes until the milky solution (pre-emulsion) was formed, followed by a 10-minute sonication. Finally, the polymerization process was conducted with a mechanical stirrer (100 rpm) for 24h.

Pressure Treatment of Rubberwood

Rubberwood (*Hevea brasiliensis*) blocks measuring 19 x 19 x 19 mm with no physical defects (decay, knots, borers attack, etc.) were oven-dried at 60°C for 24 - 48 h to constant weight prior to treatment. Wood blocks were pressure treated (~25 mm Hg) with the nanoencapsulated rotenone using six concentrations (0.5, 1, 3, 5, and 15 wt%) for 30 min. After 48 h of treatment, blocks were air-dried for another 48 h. Weight after treatment and drying was recorded. The rotenone nanocapsule retention in treated wood was then calculated based on the weight-gain method (Donath et al. 2004). Untreated rubberwood, rubberwood treated with rotenone (no encapsulation), and capsules only were also prepared and used as control and comparison.

Exposure to Insect Wood Borer

A laboratory insect test was carried out to determine the toxic values of different concentrations of nanoencapsulated rotenone against adults of the wood boring beetle, *Minthea reticulata* (Coleoptera: Bostrichidae: Lyctinae). Five newly emerged adults of *M. reticulata* were collected from infested untreated rubberwood that was stored in a box. The wood borers were carefully placed into a glass jar containing wood samples and enclosed with wire mesh fabric tied with a rubber band

(Figure 1). Five (5) replicates were used for a total of 25 adults of *M. reticulata*. Each test sample was kept under ambient laboratory conditions (T=26 ± 2°C, RH = 70 ± 5%). The number of dead insects (mortality rate) and the number of holes made by the wood borers were recorded daily for 14 days.

Figure1 Laboratory test set up to evaluate the durability of wood treated with rotenone nanocapsules against insect borer

RESULTS AND DISCUSSION

The powderpost beetle, *M. reticulata* mortality (%) after 14 days of exposure to rubberwood treated with different concentrations of rotenone nanocapsules were evaluated as in Figure 2. Mortality rate achieved 100% within 13 to 14 days of exposure on all treatments and control. More than 60% of mortality was observed after only 4 days of exposure to rubberwood treated with 3%, 10% of encapsulated rotenone and rotenone. This indicated the fast biocidal effects of nanoencapsulated rotenone on wood borers that are comparable to rotenone, compared to low concentrations of 1% encapsulated rotenone and rubberwood blocks without the rotenone (capsules only and untreated).

Signs of holes made by the beetles were detected on some of the treated rubberwood samples, but no oviposition (eggs laying) activities were observed by the adult females of *M. reticulata*. This might be due to the ingestion of toxic rotenone before the oviposition could happen with 100% mortality at the end of the 14 days of the test. Adult wood borers usually mate after emerging from the infested wood, and oviposition activities occur soon after. Females will bite on the wood to access its suitability for oviposition by determining the optimal starch content and wood moisture content (Kartika & Yoshimura 2013).

Control samples treated with blank capsules and untreated samples showed 100% mortality after 14 days. The death rate for samples with blank capsules and untreated samples was slower within the first week compared to the treated samples. The wood borers' death on the control samples might be due to the beetles' inability to utilise the rubberwood as a food source and eventually died due to starvation.

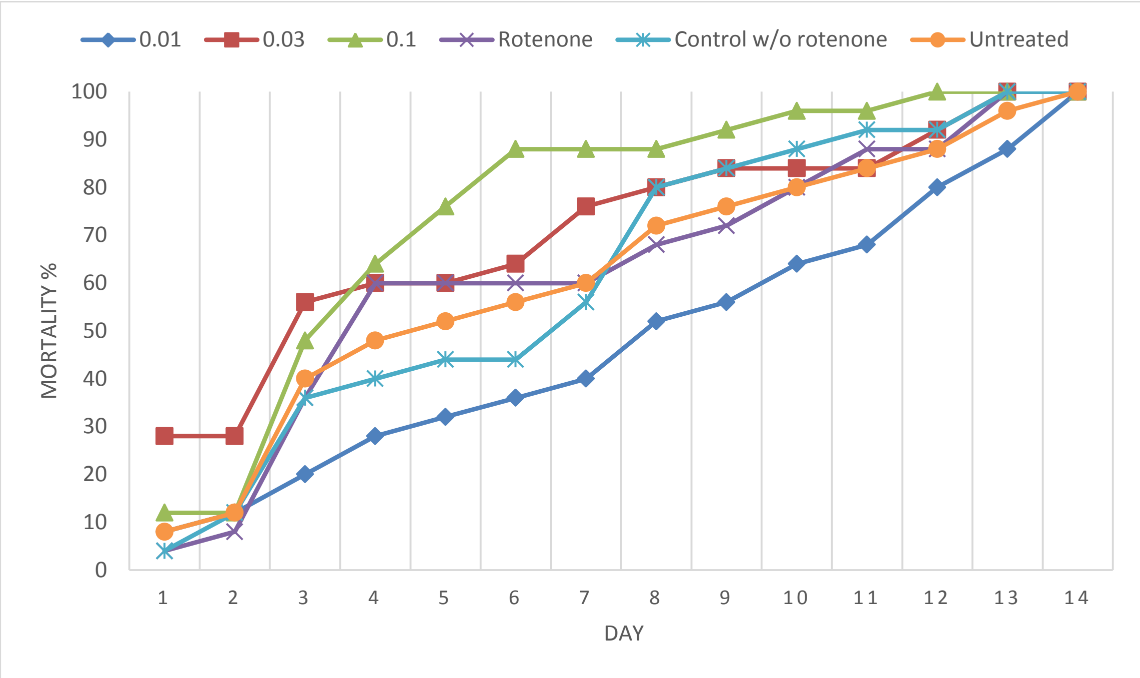

Figure 2 Mortality (%) of the powderpost beetles, *M. reticulata* after 14 days of exposure to the rubberwood treated with 1%, 3%, and 10% of nanoencapsulated rotenone compared to control and untreated rubberwood

CONCLUSION

The nanoencapsulated rotenone showed promising alternatives to protect wood against powderpost beetles. A study to evaluate the long-term efficacy of the preservatives is still ongoing. Future studies will include the possible application for protecting other wood species and lignocellulosic materials such as bamboo.

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NATURAL PRODUCTS

DEVELOPMENT OF MALAYSIAN HERBAL MONOGRAPHS

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Due to the growing demand in the herbal market, efforts have been made under the National Key Economic Area to identify high-value botanical drugs that contribute to the transformation of herbal products into nutraceuticals. The development of Malaysian Herbal Monographs (MHM) is a progressive activity on Malaysian medicinal plants relevant to local species, geographical, and environmental conditions. The monographs provide appropriate documentation for the authentication of raw materials, traditional uses, safety and efficacy data of herbal plants and their products to meet the industrial needs in accordance with general or international requirements by strengthening the supply value chain since it is applicable to raw materials, extracts, or herbal products. The Technical and Main Monograph Committees were established to drive the development of the monographs. They are headed by agencies from the Ministry of Health and include representatives from universities, government regulatory bodies, and research institutions including IMR, NPRA, FRIM, MARDI, UKM, UPM, and USM. To date, FRIM has developed and completed nine monographs since 2011, with an additional three pending for 2022. It is envisioned that the monographs will serve as a useful reference for researchers, academicians, quality control personnel, manufacturers, traders, and stakeholders of the herbal industry, specifically for regulatory or registration applications for herbal products.

Keywords: Herbal monograph, herbal plant, medicinal plant, raw material

INTRODUCTION

A herbal monograph is a document that defines a botanical medicine and contains information for its correct identification. There is a basic description of the herb used for therapeutic purposes, including nomenclature, parts used, constituents, range of application, contraindications and side effects, incompatibilities with other medications, dosage, uses, and effects of the herb (WHO 2000).

The development of the Malaysian Herbal Monograph (MHM) has been identified as one of the driver projects for agriculture, formerly known as the Entry Point Project (EPP) under the National Key Economic Area (NKEA) of the Ministry of Agriculture and Food Industry and has been designated since 2011 as the EPP#1 NKEA project. The implementation of the MHM development project is made through the establishment of the Malaysian Herbal Monograph Committee led and chaired by agencies of the Ministry of Health, Malaysia and whose members composed of representatives from universities, research institutions, and the Ministry of Agriculture and Food Industry (Terence et al. 2020).

Malaysian herbal monograph started with three volumes published in 1999, 2010, and 2013 respectively. Each volume lists 20 different plant species. These monographs, developed by a dedicated committee, consist of quality parameters of herbal medicines and include plant descriptions, macroscopic and microscopic evaluations, acceptable foreign organic matter, total ash and moisture content parameters, qualitative chemical evaluations, chromatographic evaluations, toxicological studies, and other information such as traditional use and chemical compounds.

Under the provisions of the NKEA since 2011, FRIM is responsible for developing and completing nine herbal monographs consisting of patawali stems (*Tinospora crispa*), gelenggang leaves (*Senna alata*), karas leaves (*Aquilaria malaccensis*), cekur rhizomes (*Kaempferia galangal*), cucur atap leaves (*Baeckea frutescens*), legundi leaves (*Vitex negundo*), noni leaves (*Morinda citrifolia*), pokok kapal terbang leaves (*Chromolaena odorata)* and tunjuk langit seeds (*Swietenia macrophylla*). These monographs were published and accessible in digital form (Globinmed website) for public interest. FRIM is currently working on three monographs, namely asam jawa fruits and leaves (*Tamarindus indica*) and pokok melaka leaves (*Phyllanthus emblica*). These are common herbs used in Malaysia with the availability of products based on the particular herbs. The aim of this article is to describe briefly the development of the three monographs in line with government initiatives to ensure the quality and safety of herbal medicinal products.

MATERIALS AND METHODS

The workflow for MHM data preparation is illustrated in Figure 1. A list of standard operating procedures (SOPs) created and published based on the MHM development process was used to ensure a harmonized and standardised framework by all competent agencies. It is also important to ensure that a standardized process is followed by all stakeholders to meet regulatory requirements when registering a product. The SOPs cover all the scopes of MHM, including identification, purity and safety testing, medicinal uses, pharmacological activities, and safety information.

RESULTS AND DISCUSSION

Authentication is an important issue in the industry using natural extracts. The composition of natural extracts, which determine the potency, safety, and quality of a product, is influenced by factors such as botanical species, geographical origin, cultivation, age of the plant, harvesting practices, as well as the extraction process. The World Health Organization (WHO), the United States Food and Drug Administration (USFDA), and the European Medicines Agency (EMEA) have stated that species authentication is one of the first analyses performed to ensure quality and discrimination against related or adulterated samples. Therefore, a fast and accurate analytical approach is essential to identify the right use of raw materials.

The objectives of the MHM development project are, firstly, to prepare and develop appropriate monograph documentation and verification tests for raw material validation, safety and efficacy data to meet the needs of the herbal medicines to comply with local and international requirements, and secondly, to carry out the development activities of the Malaysian Herbal Monograph as determined by members of the MHM Technical Committee and Main Committee. The results of this collaborative project are published in printed or digital form (Globinmed site) for the benefit of the public. Each agency/institution involved has the task of contributing and sharing its expertise to the development of MHM through activities such as technical training and regular awareness training.

For data generation, each raw material examined was obtained from at least three sources in Peninsular Malaysia. The resource selection criteria depend on the availability of the raw material, especially from plantations.

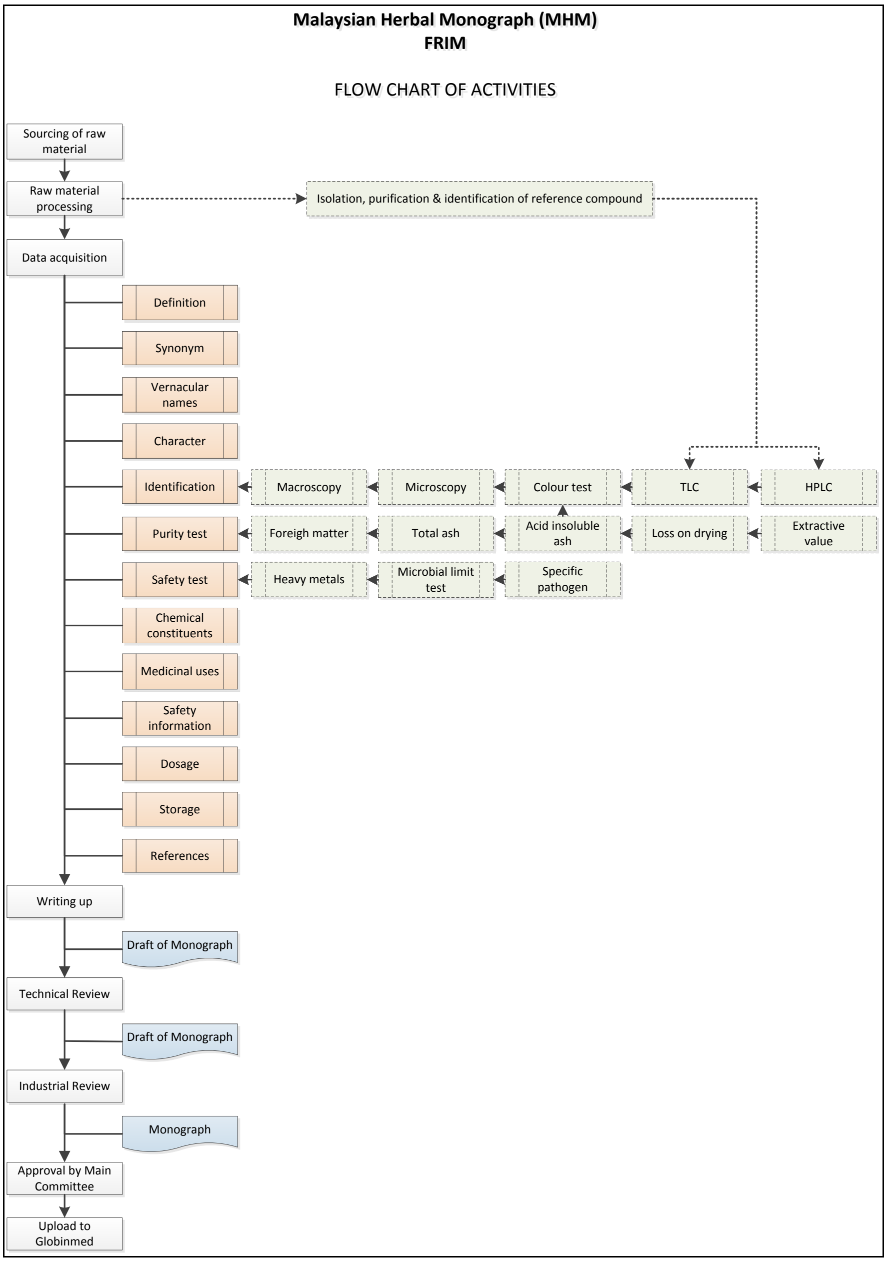

Figure 1 Workflow of research in the development of herbal monograph

Development of Monograph for Asam Jawa

Individual leaf and fruit samples from asam jawa were obtained from Kedah, Kelantan, and Terengganu (Figure 2). Microscopic identification and purity testing including foreign matter, total ash, acid insoluble ash, loss on drying, extractive values, and safety testing (heavy metals, microbial limits, and test for specific pathogens) have been carried out. HPLC and HPTLC analysis methods have been developed (Figure 3). The HPLC analysis is repeated for the system suitability test.

Figure 2 Sampling activities for asam jawa

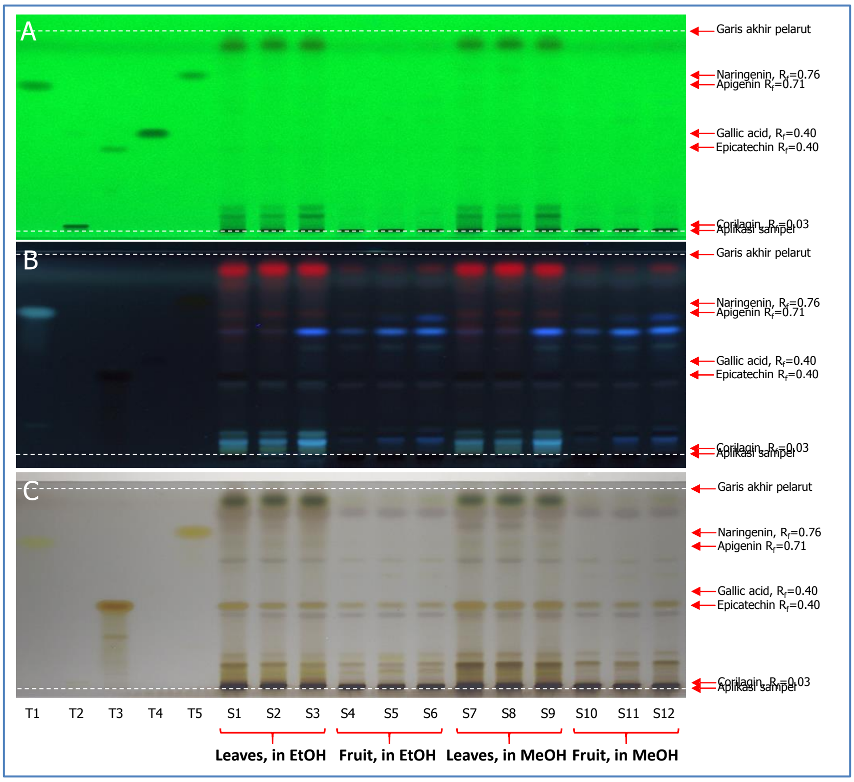

Figure 3 HPTLC chromatograms. A-254 nm; B-366 nm after derivatisation with 10% H_2SO_4; and C-visible light after derivatisation with 10% H_2SO_4. T1-Apigenin; T2-Corilagin; T3-Epicatechin; T4-Gallic acid; T5-Naringenin. S1-S12-asam jawa from various locations

The writing up for the drafts of both asam jawa fruits and leaves are 44% complete with the remaining 16% including HPTLC and HPLC profiling. Once the drafts are finalised, the remaining 40% will be devoted to MHM's technical and industrial verification.

Development of Monograph for Pokok Melaka

The leaves of pokok melaka were obtained from Terengganu, Selangor, and Melaka (Figure 4). There are species that are closely related to *P. emblica*, namely *P. pectinatus*. The two are very similar morphologically and are difficult to distinguish without fruit material. In addition, locals also use the local name pokok melaka for both species. Of the 3 locations, only one sample was confirmed as *P. emblica* and the other 2 locations were confirmed as *P. pectinatus* based on fruit and seed morphology, i.e. the fruits of *P. emblica* are often found clustered at the base of the leaves, whereas, in *P. pectinatus* they appear only at the tips of the shoots. Another diagnostic feature is that the seed of the fruit is sharply 3-angled in *P. pectinatus* but more rounded in *P. emblica* (Figure 5). The chemical profiling results also showed the differences between the two species (Figure 6).

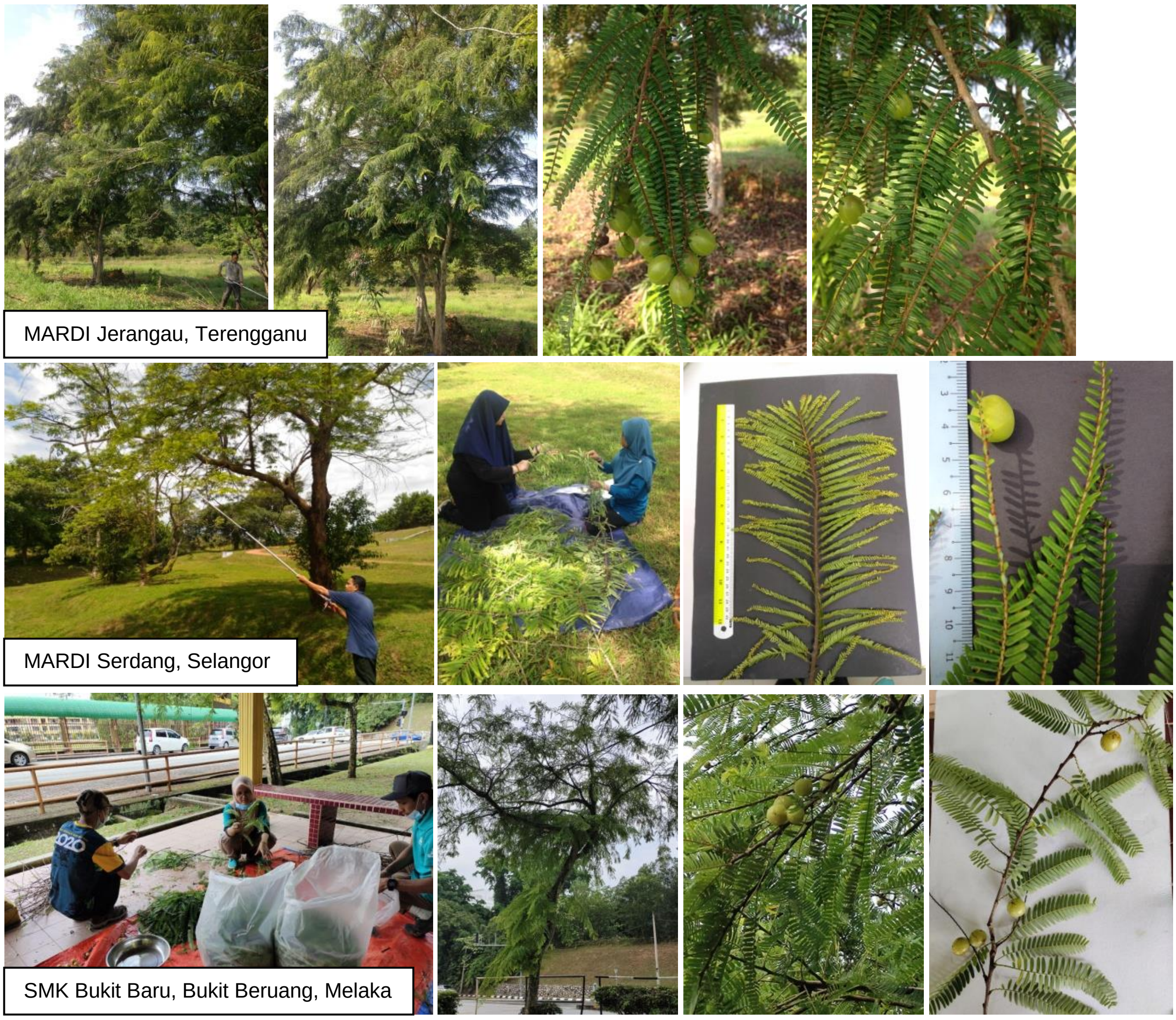

Figure 4 Sampling activities for pokok melaka

A B C D

Figure 5 Fruits of *P. emblica* (A) and *P. pectinatus* (B); Fruit and seeds of *P. emblica* (C) and *P. pectinatus* (D)

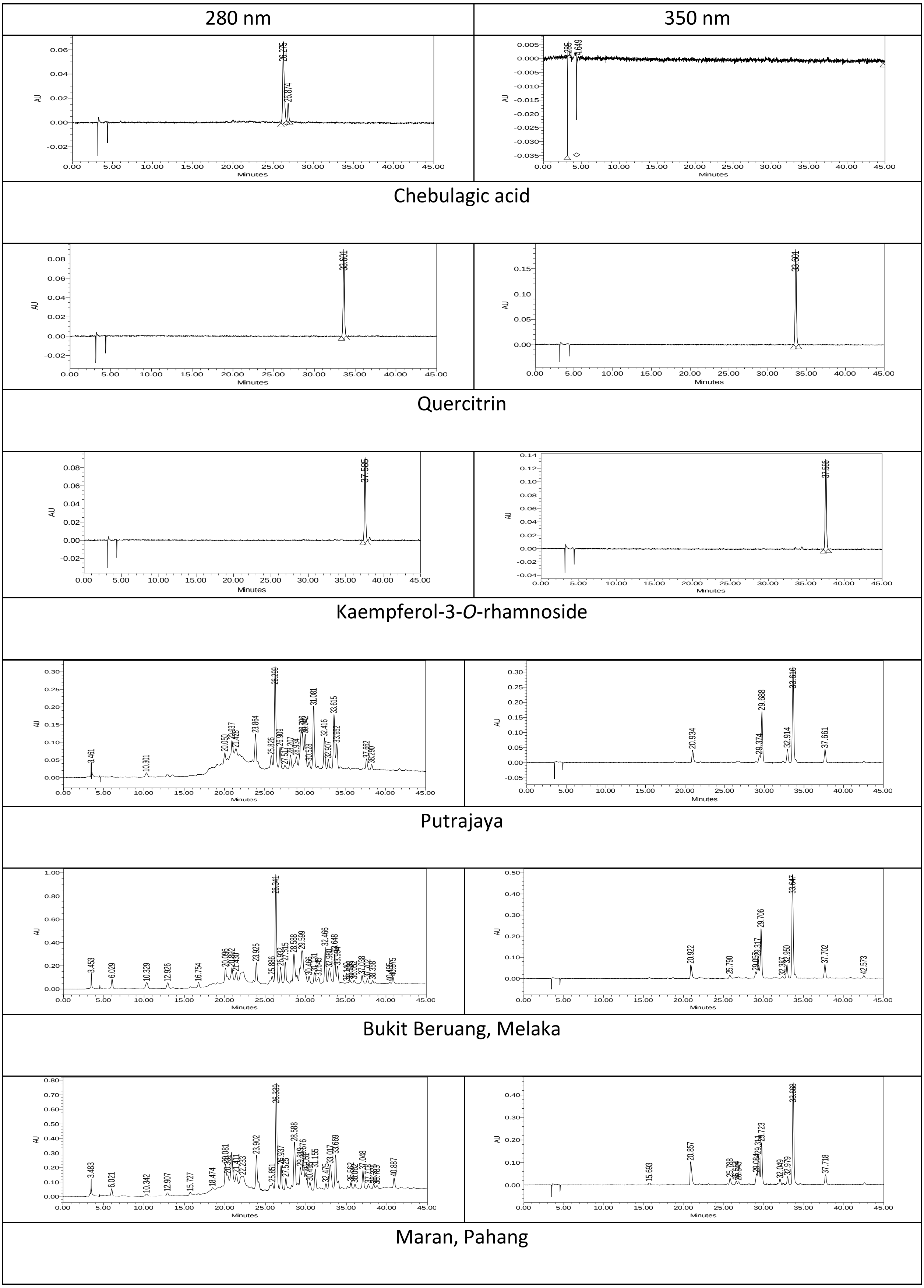

Figure 6 HPLC profiles of chebulagic acid, quercitrin and kaempferol-3-*O*-rhamnoside and pokok melaka leaves

The writing up for the draft of pokok melaka leaves is 32.7% complete. Another 27.3% relates to the HPTLC and HPLC profiling, purity, and safety tests currently in progress. Once the draft is complete, the remaining 40% is for verification testing and MHM technical and industrial review.

CONCLUSION

FRIM's involvement, role, and experience in the development of Malaysian herbal monographs (MHM) have spanned more than 20 years. Prior to the involvement of the Ministry of Agriculture & Agro-based Industry (MOA), FRIM had coordinated the publication of 3 volumes of MHM with 60 species of medicinal plants directly into the development of monographs for 9 species of medicinal plants and herbs under the NKEA project, MOA. An advantage of FRIM, often referenced by other agencies when developing MHMs, is its ability and expertise in identifying and purifying chemical compounds from plant species as markers for herbs. Most of the purified chemical compounds are very valuable and also cannot be bought on the market. These chemical compounds form the basis for analyzes such as method development, stability studies, in vitro and in vivo studies, identity checks, and characterizations as internal references. FRIM can be further strengthened as a reference center and source of plant-based quality assurance marker compounds that can provide selected chemical compounds for use by industry. This will directly contribute to revenue generation in the future.

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IN VITRO ANTI-CHOLESTEROL STUDY AND HPLC ANALYSIS OF *ANNONA MURICATA* LEAVES AQUEOUS EXTRACT

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Annona muricata L. (Magnoliales: Annonaceae) is a tropical plant species from the Annonaceae family that has been widely studied in the last decades due to its therapeutic potential. Traditionally, the leaf of *A. muricata* was used for managing blood cholesterol level. Cholesterol is a sterol class of fats or lipids produced by the body. At a certain rate, cholesterol is needed by the body for the formation of essential components. The normal rate of plasma cholesterol is 160-200 mg/dL. A higher rate of cholesterol in the blood plasma will cause a higher risk of atherosclerosis. Atherosclerosis causes the thickening and hardening of blood vessels by cholesterol. As reported previously, *A. muricata* has been used in managing blood cholesterol levels, therefore this study aimed to investigate the chemical compounds responsible for the anti-cholesterol activity. Phytochemistry studies on *A. muricata* leaves have successfully isolated rutin and nicotiflorin. These two compounds were reported to show significant activity for anti-cholesterol. In this study, water extract of *A. muricata* (AMWE) leaves was prepared by boiling (100^{o}C) dried and ground leaves in water for 1 hour. The solution was left to cool and filtered. The filtration was then freeze-dried into powder. Quantitative HPLC analysis revealed that the average percentage (w/w) of rutin and nicotiflorin in water extract were 0.53 and 0.60% respectively. Besides that, *in vitro* HMG Co-A reductase (HMGR) enzyme test was performed on the AMWE, rutin, and nicotiflorin. The result showed that *A. muricata* aqueous extract could reduce the activity of HMGR activity with an inhibition percentage of 60%. Rutin and nicotiflorin showed an inhibition percentage of 50 and 70% respectively. In conclusion, the presence of rutin and nicotiflorin in the extract has contributed to reducing HMGR activity, hence could act as an HMGR inhibitor and can be used adjunctively in diet and exercise to treat hypercholesterolemia.

Keywords: *Annona muricata*, leaves water extract, phytochemistry, HMG CoA reductase, anti-cholesterol

INTRODUCTION

Graviola (*Annona muricata*) is a small tropical evergreen fruit tree, belonging to the Annonaceae family, and is widely grown and distributed in tropical countries (Rady et al. 2018). *Annona muricata* has been widely studied in the last decades due to its therapeutic potential (Coria-Télleza et al. 2018). Numerous investigations reported that *A. muricata* can act as anticancer, anticonvulsant, anti-arthritic, antiparasitic, antimalarial, hepatoprotective, antidiabetic, analgesic hypotensive, anti-inflammatory, and immune-enhancing effects (Patel & Patel 2016).

Phytochemical studies have been extensively performed on different parts of *A. muricata* and to date, 212 secondary metabolites have been isolated and identified, such as acetogenins, alkaloids, phenolic compounds, and megastigmanes (Abdul Wahab et al. 2018). The most widely used preparation in traditional medicine is the decoction of the leaf. The ingestion of leaves decoction is used as an analgesic in Brazil (Ross 2010). Natives of Malaysia used *A. muricata* leaves to treat cutaneous (external) and internal parasites (Badrie & Schauss 2009). The use of leaves to treat malaria is very important in tropical countries such as Cameroon, Togo, and Vietnam (Boyom et al. 2011). However, the study of *A. muricata* leaves to treat hypercholesterolemia is still scant. Many data revealed that cholesterol biosynthesis can be controlled by active compounds extracted from natural sources such as the leaves of the herb.

The intake of dietary cholesterol is usually associated with an increased intake of saturated fatty acids which was reported to increase LDL Cholesterol and therefore increase the risk of atherosclerosis and cardiovascular disease (Hu et al. 2001). Besides that, cholesterol has also been produced by the human liver for body needs. Cholesterol synthesised by the liver, as well as any dietary cholesterol in the liver that exceeds hepatic needs, is transported in the serum within LDL. An increase of LDL in the blood is the risk factor for hypercholesterolemia-related diseases. Therefore, reducing cholesterol liver biosynthesis by reducing HMG-CoA reductase (HMGR) is among the best strategy to reduce cholesterol in the bloodstream. There are many HMGR inhibitors drug that is commercially available. Also known as statins, it was used adjunctively in diet and exercise to treat hypercholesterolemia by lowering total cholesterol (TC), low-density lipoprotein cholesterol (LDL-C), and triglycerides (TG) concentrations while increasing high-density lipoprotein cholesterol (HDL-C) concentrations (Bansal 2020). However, statin drug families could cause many sides effect after being used for a long period.

This study aimed to determine the ability of water extract of *A. muricata* leaves to reduce the HMGR activity. HMGR is the rate-limiting enzyme of cholesterol biosynthesis (Jiang et al. 2018). So, any compounds from *A. muricata* that can reduce HMGR activity will act as a natural HMGR inhibitor.

MATERIALS AND METHODS

Preparation of the 10% *Annona muricata* Water Extract (AMWE)

A. muricata dried leaves were obtained from Ethno Resources Sdn Bhd, Sungai Buloh. Extract preparation was based on Adewole et al. (2009) with slight modification. The leaves were ground into a fine powder using an electric blender. Next, 100 g powder was boiled in 1000 ml RO water for 1 h. The solution was filtered, and the supernatant was concentrated by using rotavapor at 50 ^{o}C and freeze-dried into powder. The 10% powder extract of AMWE was stored at -80 ^{o}C until use.

HMG-CoA Reductase Test

HMG-CoA reductase activity was studied using a kit provided by Sigma (USA). The assay was performed as described by (Falé et al. 2013) by quantifying NADPH at 0, 1, 2, 4, and 6 min in reaction mixtures containing 5 mg/ml of samples (rutin, catechin, nicotiflorin, and AMWE). The percentage of HMGR activity by each sample was calculated as enzyme activity (%) = 100 × (v sample/v control), where v sample is the initial rate of enzymatic reaction for the sample and v control is the initial rate for the control reaction in the absence of the sample. Pravastatin, a commercially available drug to lower cholesterol, was purchased from Sigma (USA) and used as a positive control.

HPLC Analysis: Preparation of Test Samples

Five ml of methanol was added to 0.5 g of sample in a 14 ml volume vial. The mixture was placed in an ultrasonic machine for 15 minutes. The solution was filtered with a syringe filter using a 0.45 μm PTFE cartridge before analysis.

Preparation of Standard Solutions of Reference Compounds

The reference compounds rutin and nicotiflorin were weighed separately and dissolved in methanol to 500 μg/ml. A series of solutions with a concentration range of 70 - 350 μg/ml are available for calibration plots.

HPLC Analysis Method

HPLC analysis was carried out using a UPLC WATERS ACQUITY system and equipped with a Luna Omega C18 column (150 x 2.1 mm, 3 μm). Gradient elution was performed at room temperature with solution A (0.1% formic acid in water) and solution B (acetonitrile) in the following gradient elution program: 0–2 min–95 % of solution A; 2–6 min–90 % of solution A; 6–7.2 min–80 % of solution A; 7.2–9 min–75 % of Solution A; 10.8–12 min–65 % of solution A; 12–15 min–50 % of solution A and 15 min 40% of solution A. Flow rate was set to 0.39 ml/min and injection volume was 10 μl. Detection was examined at 280 nm.

RESULTS AND DISCUSSION

As shown in Figure 1, treatment of AMWE only showed 40% of HMGR activity. This suggests that the extract can reduce HMGR activity by 60% and act as a cholesterol-reducing agent, probably by a statin-like mechanism. Both compounds, rutin and nicotiflorin also inhibit HMGR activity, even if their inhibition percentage were lower than the commercial hypocholesterolemic drug simvastatin. The presence of rutin and nicotiflorin in the extract can explain 60% of the HMGR inhibition. Previous studies reported that rutin was recognized as an HMGR inhibitor (Suganya et al. 2017). The remaining HMGR inhibition activity can be ascribed to the other phenolic acids derivatives, as well as the flavonoid derivatives such as catechin.

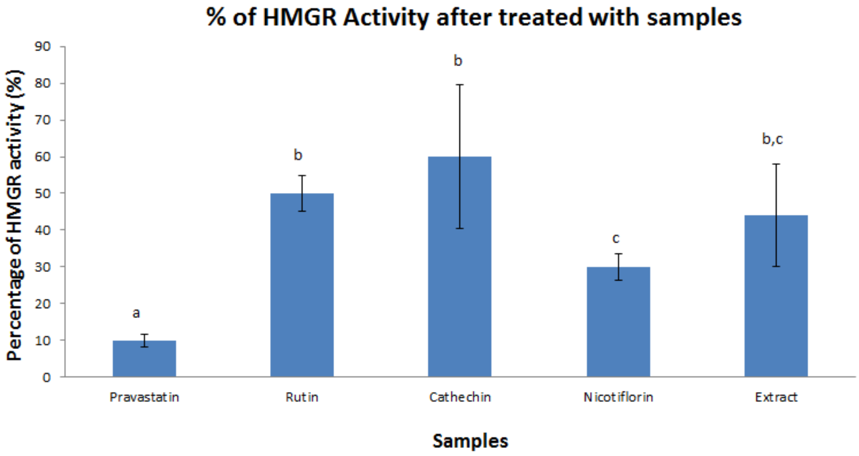

Figure 1 Percentage of HMGR activity after treated with rutin, catechin, nicotiflorin and AMWE extract. Pravastatin was used as a positive control. All data were presented as the mean ± SD of triplicates

HPLC qualitative analysis of aqueous extract of *A. muricata* leaves shows the presence of rutin at a retention time of 7.697 min and nicotiflorin at a retention time of 8.335 min (Figure 2). Therefore, the quantitative analysis of rutin and nicotiflorin was performed to obtain the concentration of both compounds in the extract. The analysis was performed in triplicate and the results were tabulated in Tables 1 and 2.

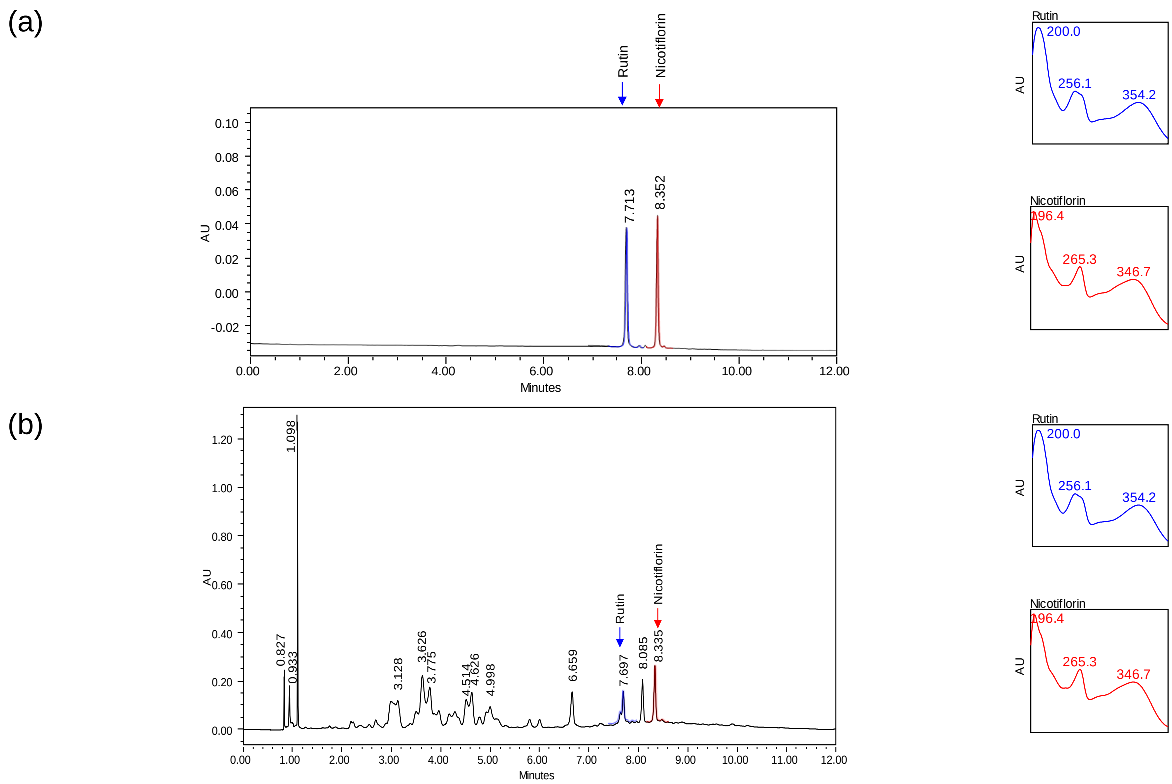

Figure 2 HPLC chromatograms of and UV absorbance of (a) rutin and nicotiflorin; (b) *A. muricata* aqueous extract at wavelength of 280 nm

Table 1 Quantitative analysis of rutin in the extract

Sample	Concentration of rutin (ppm)		Average concentrations of *rutin* ± RSD (ppm)	Percentage of rutin in the sample (w/w)		Average percentage of rutin in the sample ± RSD (w/w)
Aqueous extract of *A. muricata* leaves	Rep 1	51.72	51.75±0.14	Rep 1	0.53	0.53±0.14
	Rep 2	51.70		Rep 2	0.54	
	Rep 3	51.83		Rep 3	0.52	

Table 2 Quantitative analysis of nicotiflorin in the extract

Sample	Concentration of nicotiflorin (ppm)		Average concentration of nicotiflorin ± RSD (ppm)	Percentage of nicotiflorin in the sample (w/w)		Average percentage of *nicotiflorin* in the sample ± RSD (w/w)
Active Fraction (Batch 1)	Rep 1	59.88	59.99±0.23	Rep 1	0.60	0.60±0.23
	Rep 2	59.94		Rep 2	0.61	
	Rep 3	60.14		Rep 3	0.60	

CONCLUSION

The study concluded that the aqueous extract of *A. muricata* has a promising anti-cholesterol effect with 60% HMG-CoA reductase inhibition activity. HPLC qualitative and quantitative analysis observed the presence of rutin and nicotiflorin in the extract with the w/w concentration of 0.53 and 0.60% respectively. The presence of both compounds and other phenolic and flavonoid compounds may contribute to the anti-cholesterol effect.

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DEVELOPMENT OF STANDARDISED EXTRACT FROM MEDICINAL PLANT (ABP016) BASED ON ORANG ASLI TRADITIONAL KNOWLEDGE TOWARDS PRODUCTION OF PROTOTYPES

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Bioprospecting initiative on selected medicinal and aromatic plants based on orang asli traditional knowledge has led to the discovery of the anti-inflammatory property of ABP016—a medicinal plant species from Zingiberaceae family. This species has been used traditionally by eight orang asli sub-ethnics in Peninsular Malaysia, as an external application mainly for treating fever, flu, and eye infection. This project was carried out to explore the commercialization potential of ABP016 as a therapeutic agent and cosmeceutical products through the development of standardized extract and product prototypes. To ensure the availability of raw material supply for commercial purposes, a study on the production of planting material was also conducted in this project. Four trial plantation plots were established at four orang asli settlements to determine the best planting technique and optimal growth performance of ABP016 species. Rhizome samples were collected at the age of 9, 12, and 15 months for evaluation of anti-protein denaturation activity and chemical profiling of lab-scale standardized extracts. All rhizomes were harvested from trial plots at 15 months for pilot scale extraction. In addition, a series of assessments were also conducted, which include biological assays and chemical profiling, safety assessment on raw materials, and standardized extracts. An active ingredient containing ABP016 standardized extract was then used for the formulation of personal care products. Results showed that ABP016 planted with raised bed method produced the highest rhizome biomass at 15 months. A standardized extraction protocol of ABP016 rhizome was successfully developed at laboratory and pilot scales. The anti-protein denaturation activity exhibited by the 12 months extract was higher than at 9 and 15 months extracts. However, similar chemical profiles of the rhizome extracts at different growth periods were obtained from HPLC analysis. For safety assessments, the pilot scale extract showed low cytotoxic, non-mutagenic, and no acute toxic effects. In line with the traditional uses of ABP016 particularly to relieve fever and control body heat, a range of personal care products which include face & body mist, shower gel, bar soap, and body lotion have been developed, as a way to modernize and simplify traditional applications. The selected product was tested and classified as non-irritant to the human skin and eyes. Overall, this project has produced standardized plant extract, active ingredients, and suitable products from orang asli traditional knowledge with efficacy, quality, and safety data. Commercialisation of natural products based on traditional knowledge and supported by scientific findings will ultimately benefit the communities and the herbal industry in the future.

Keywords: Traditional knowledge, orang asli, Zingiberaceae, medicinal plants

INTRODUCTION

Medicinal plants used by the local indigenous community have always created interest as a starting material in the search of novel agents for pharmaceuticals, nutraceuticals, and cosmeceuticals because of their uniqueness and known healing power. From the documentation project of orang asli traditional knowledge (TK) on medicinal and aromatic plants involving all 18 sub-ethnics in Peninsular Malaysia, selected plants species were tested to validate their traditional claims and/or to discover their new therapeutic potentials. As a result, a medicinal plant species from the Zingiberaceae family coded as ABP016 was discovered with anti-inflammatory properties.

The ABP016 species has been used traditionally by eight orang asli sub-ethnics from eight locations in Peninsular Malaysia, which include sub-ethnics Jahai and Temiar (Gerik, Perak), Semai (Gopeng, Perak) Lanoh (Lawin, Perak), Temiar (Lojing, Kelantan), Semoq Beri (Kuala Berang, Terengganu), Mendriq (Gua Musang, Kelantan), Semelai (Jempol, Negeri Sembilan) and Temuan (Jelebu, Negeri Sembilan). Although used by different sub-ethnics and documented from different locations, the traditional uses are quite similar, i.e., where the water inside the inflorescence is used to moisten the patient’s head to relieve fever. It was also recorded that the inflorescences, leaves, and stems are soaked in bath water to treat fever, flu, and cough. Besides, the decoction of rhizomes and roots is said to be used to relieve headaches. Findings from laboratory studies showed that various parts of this plant exhibited high anti-inflammatory effects that could support its traditional uses to reduce inflammation related-conditions (Nurul Haslinda et al. 2021). Therefore, ABP016 was selected to be developed as a quality standardized extract for the production of herbal products based on orang asli TK.

To commercialise herbal products of ABP016, there must be sufficient raw material at hand not to mention its quality. Sourcing raw materials from the forests may be one available option. Nonetheless, the quantity and quality of herbal products cannot simply be compromised should there is a plan to expand its sales horizon or venture into commercialization activity. Therefore, to ensure a sufficient supply of and quality ABP016 material for the production of the so-called herbal products in the future, setting up trial plots and later probably large-scale planting just cannot be avoided.

MATERIALS AND METHODS

Determination of Optimal Planting Techniques and Growth Performance

The ABP016 was collected from forests reserve and nearby community settlements. In the 1^{st} phase of ABP016 planting study, an approach of individual planting of the trial plot was introduced. During this phase, the seedlings were planted directly on site after they were collected. In the 2^{nd} phase (community planting), the seedlings were grown in the FRIM’s nursery first for 3 months before being planted as trial plots. Each trial plot established consisted of three planting techniques, which were raised bed, flat bed, and polybag. Growth monitoring and rhizomes sampling were recorded every three months. Table 1 shows the establishment of ABP016 trial plots at different locations.

Table 1 List of ABP016 trial plots established at orang asli settlements

Plot	Plot location	Sub-ethnic	No of participant	Planting technique
Individual	RPS Banun, Gerik, Perak (ABP)	Jahai, Temiar	21	1. Raised bed 2. Flat bed 3. Polybag
	Kg Ulu Geroh, Gopeng, Perak (UGG)	Semai	10	
Community (group)	Kg Sg Lui, Jempol, Negeri Sembilan (SLJ)	Semelai	30	
	Pos Tuel, Lojing, Kelantan (PTL)	Temiar	30	

Development of Laboratory and Pilot Scale Extraction Protocols

ABP016 rhizome samples were collected at the age of 9, 12, and 15 months for the lab-scale extraction. Briefly, the rhizomes were cleaned, cut into small pieces, and dried in an oven. The dried materials were ground into powder and used for water extraction following determined parameters (FRIM ID 39/2018) and then freeze-dried.

For pilot scale extraction, ABP016 rhizomes were harvested from trial plots at the age of 15 months and processed accordingly. The post-harvest processing and sample extraction were conducted at Pusat Teknologi Lepas Tuai, SPF Maran, Pahang, and Pusat Teknologi Herba, FRIM, respectively. A slight modification in drying and extraction protocols was introduced to meet the facility requirements. In addition to the standardized rhizome extraction, an essential oil extraction protocol was also developed at Pusat Teknologi Minyak Pati, FRIM.

Evaluation of Biological Activities, Chemical Profiling, and Safety Assessment

The anti-inflammatory activity of ABP016 standardized extract was determined using anti-protein denaturation and anti-protease assays. In addition, antioxidant activity was also tested on pilot scale extract using anti-elastase and anti-collagenase assays. Chemical profiling of the extracts and essential oils was performed using high-performance liquid chromatography (HPLC) and gas chromatography-mass spectrometry (GC-MS), respectively. For safety assessment, testing performed on the pilot-scale extract were cytotoxicity (MTT assay), acute toxicity (OECD 420), mutagenicity (OECD 471), microbial contamination, and heavy metal contents (BP 2016). The raw materials were tested for microbial contamination and heavy metal contents only.

Development of Product Prototype

The product prototypes were developed based on the traditional uses of ABP016 species and guided by the results of biological evaluations that can support the application of the product scientifically. The ABP016 standardized rhizome extract was first formulated into an active ingredient before being incorporated into products. The final formulation of the selected product was sent for related product safety testing at SIRIM. After that, the selection of the product name, tagline, label design, bottle, and packaging were finalised.

RESULTS AND DISCUSSION

As mentioned earlier, a sustainable supply of quality raw materials and little dependency on natural resources from the forests play an important role in the supply chain of herbal products. Our experience in establishing trial plots for bulk harvesting of ABP016 rhizomes with orang asli communities showed that community planting had more advantages and contributed to conclusive findings than individual planting (Siti Salwana et al. 2021). Based on the community planting at SLJ and PTL trial plots, ABP016 rhizomes biomass produced by raised bed technique (43%) was significantly ($p<0.01$) higher than flatbed (20%) and polybag (37%) techniques, with the average rhizome weight of 1.7 kg per plant.

The average percentage of ABP016 dried rhizomes (g/100 g fresh weight) and yield extracts (g/100 g dried material) obtained from four trial plots at the age of 9, 12, and 15 months are shown in Figure 1. Generally, the recovery rate of dried raw material and extracts were not significantly different ($p>0.05$) at three harvesting times. This could be due to the same moisture content in the rhizomes of this species at the young growth stage.

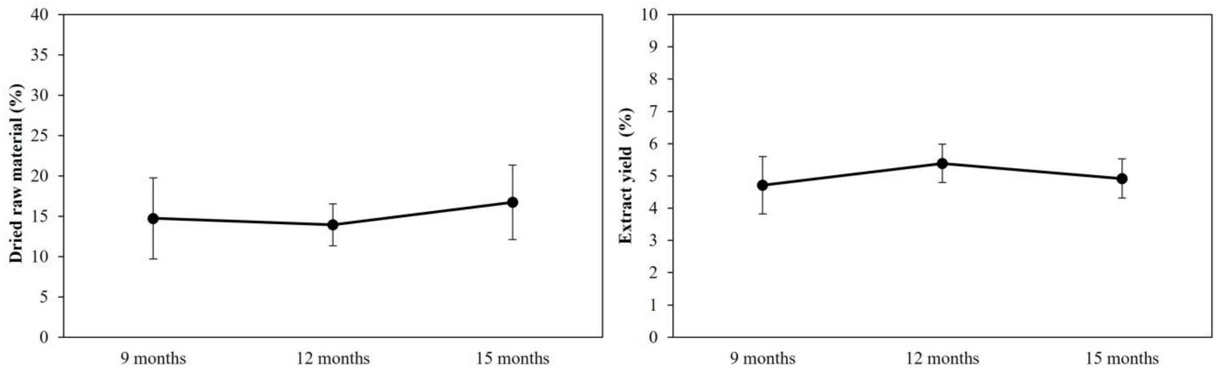

Figure 1 Recovery rate of ABP016 raw material and extract at three harvesting time

The main biological test performed to assess the anti-inflammatory activity of ABP016 extracts was the anti-protein denaturation (anti-PD) assay. The ability of a test item to inhibit protein denaturation is regarded as a mechanism for stabilizing a protein structure, preventing molecular damage, and limiting the inflammatory response (Kim et al. 2007). As shown in Figure 2, lab-scale ABP016 extracts at the age of 12 months from certain trail plots exhibited significantly ($p<0.05$) higher anti-PD activity compared to its 9 and 15 months extracts. The average anti-PD activity of lab-scale extract at 15 months from all trial plots was 64.90 ± 2.41%. However, the average anti-PD activity of the pilot-scale extract was found to be lower with inhibition of 50.16 ± 12.47%. In addition to anti-PD activity, the ABP016 extracts also exhibited anti-protease (36.22–59.33%), anti-elastase (12.87%), and anti-collagenase (6.24%) activities.

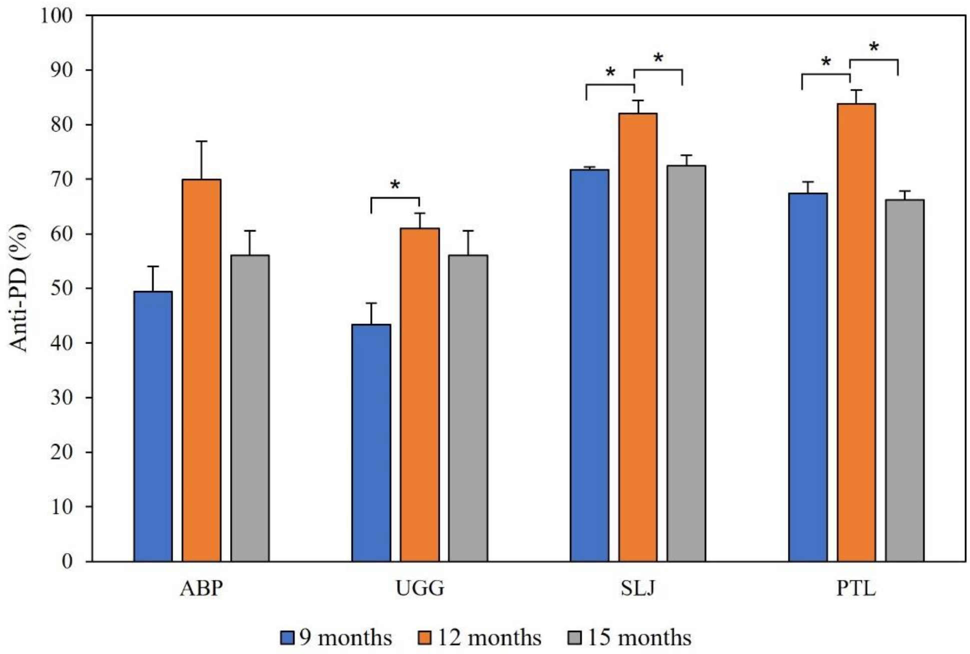

Figure 2 Anti-protein denaturation activity of ABP016 lab-scale extracts from four trial plots at three harvesting time. Extracts were tested at the concentration of 100 µg/ml. *Significant different at p<0.05, n=3

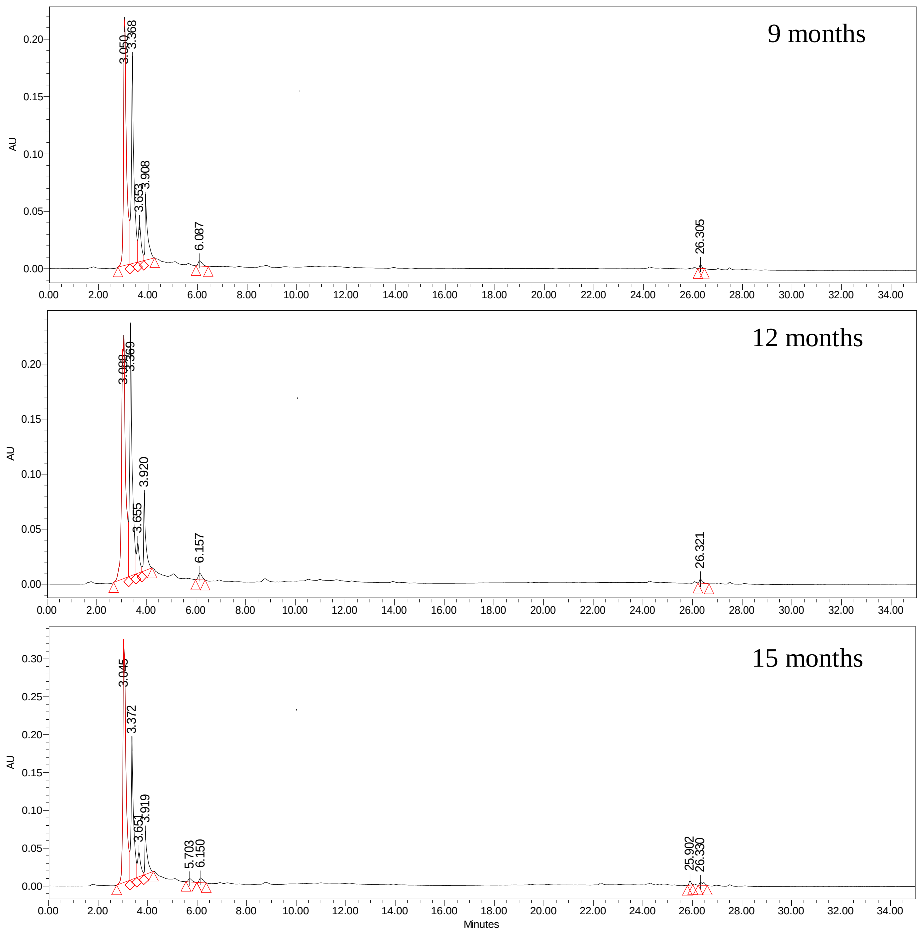

Figure 3 A representative of HPLC chromatograms of ABP016 extracts at three harvesting time

Chemical profiling of ABP016 extracts as shown in the HPLC chromatograms (Figure 3) indicated the presence of similar compounds at different growth periods. The chemical identity of the compounds is yet to be identified. On the other part, the major chemical composition in the essential oils of the rhizomes from ABP and UGG plots was terpinen-4-ol (24.49%), β-phellandrene (11.81%) in rhizomes from SLJ plot, and β-pinene (11.92%) in rhizomes from PTL plot.

For the safety assessment, the pilot-scale extract was tested on several toxicological testing. ABP016 standardized extract did not cause acute toxic effects with no mortality and adverse effects observed in a group of healthy, non-pregnant female Sprague-Dawley rats administered orally with a single dose of 2000 mg/kg body weight. The extract also did not show any mutagenic potential when tested using the bacterial reverse mutation test (Ames test). As for the cytotoxicity, extracts from different trial plots showed IC_{50} value ≥ 150 µg/ml against all the WRL-68 liver cells, Vero kidney cells, and BALB/3T3 clone A31 fibroblast cells, except for PTL extract that showed IC_{50} of 62.6 ± 11.6 µg/ml against BALB/3T3 clone A31 fibroblast cells. Heavy metal contents were within acceptable levels. However, the total aerobic microbial count (TAMC) and total yeasts and molds count (TYMC) of the ABP016 rhizomes and extracts exceeded the permitted limits. Plant parts especially rhizomes are at risk of bacterial contamination due to their nature of growth in the soil and they contain nutrients for the growth of the fungi. Several post-harvest treatments could be applied to reduce microbial contamination, such as heat or steam treatment on the raw materials, and low dose exposure of gamma irradiation on the semi-finish herbal products (Kosalec et al. 2009).

In line with the traditional uses of ABP016 particularly to relieve fever and control body heat, a range of personal care products which include face & body mist, shower gel, bar soap, and body lotion have been developed to modernize and simplify traditional applications. *SpectaCare: Beyond Tradition* was selected as the name and tagline for this prototype (Figure 4). The face & body mist product was tested and classified as non-irritant to the human skin and eyes.

Figure 4 A ranges of personal care products developed from ABP016 standardized extract

CONCLUSION

Overall, this project has successfully empowered four orang asli sub-ethnic communities to participate in the establishment and nurturing of trial plots of their valuable medicinal plant. The raw materials harvested from the trial plots were used to produce standardized plant extract, active ingredients, and suitable products from orang asli traditional knowledge with efficacy, quality, and safety data. Commercialization of natural products based on traditional knowledge and supported by scientific findings will ultimately benefit the communities and herbal industry in the future.

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PROCESSING AND STORING CONDITION OF *SONNERATIA CASEOLARIS* (BEREMBANG) FOR PRODUCTION OF FRUIT JUICE DRINKS AT COMMERCIAL SCALE

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Sonneratia caseolaris L. (Berembang) is a mangrove species that are known as one of the plants that *Pteroptyx tener* (kelip-kelip) congregate. *S. caseolaris* can be found growing along the riverside. From a previous study, it was found that the fruit is suitable to be developed into ready-to-drink fruit juice, namely Jus Laris. In this study, FRIM together with Penang Inshore Fishermen Welfare Association (PIFWA) developed a technique for processing and storing fruits for juice production on a commercial scale. Two types of processing and storing conditions of *S. caseolaris* fruits were evaluated: drying and freezing techniques. Fruits were analysed for microbial and heavy metal contamination, nutritional and vitamin C content, as well antioxidant properties. The objective of this study is to improve the quality of fruits as material for fruit juice production on a commercial scale.

Keywords: *Sonneratia caseolaris*, product development, fruit juice, commercial scale

INTRODUCTION

Sonneratia caseolaris L. or locally known as berembang is from the family Sonneratiaceae. The species produced edible fruit with a sour taste that can be found along deep muddy riverbanks, river mouths, and mangrove forests (Wetwitayaklung et al. 2013). *Sonneratia sp* is known for nectar-producing mangrove trees that attract animals like monkeys and birds as well as the insects like fireflies (Mohd Azlan et al. 2012). In Malaysia, community from the mangrove forest like in Sungai Acheh, Nibong Tebal, Pulau Pinang has consumed semi-ripe *S. caseolaris* fruits with a condiment like shrimp paste. Traditionally, *S. caseolaris* has been used to treat piles and sprain poultices (Bandaranayake 1998), as astringent and antiseptic (Ghani 2003), relieve cough, anthelmintic drugs, and arresting haemorrhage (Wetwitayaklung et al. 2013), relieve fatigue, ulcers, swelling, and boils (Nor Azah et al. 2020a).

Attributable to the interesting flavour and health benefits, a collaboration works between FRIM and PIFWA had developed Jus Laris, a ready-to-drink *S. caseolaris* fruit juice (Nor Azah et al. 2020b). Jus Laris has a unique taste and is commonly described by consumers as a refreshing drink and has a similar taste as the juice of tamarind or passion fruit. Consumers are attracted to buy the product due to their childhood memory of eating the fruit or curiosity of tasting uncommon and rare fruits.

Since then, PIFWA continuously produced the Jus Laris and was inspired to penetrate a bigger market. However, PIFWA is facing a problem in producing the juice at a larger scale due to the limitation of the fruits supply. In addition, the fruits are quite difficult to handle. The fruit fleshes tend to be mushy when ripe and might become perishable if not handled with extra care. As a solution, the fruits need to be quickly preserved after being collected prior to juice production. Therefore, the objective of this project is to determine the sustainability, quality, and safe materials for commercial-scale juice production.

MATERIALS AND METHODS

With the help of the PIFWA community, two processing methods and storing conditions for *S. caseolaris* fruits were studied, drying and freezing.

Sample Collection and Processing

Semi-ripe and ripe fruits of *S. caseolaris* were collected in the area of Sungai Acheh, Nibong Tebal Pulau Pinang. In order to collect the fruits, fishermen or the members of the community need to use a boat to reach the area where *S. caseolaris* is available. All fruits were cleaned and washed. Then the fruits were grouped into semi-ripe and ripe.

Drying Process

Cleaned semi-ripe *S. caseolaris* fruits were selected for this technique due to the lower moisture content compared to ripe fruit. The selected fruits were hand-sliced thinly, approximately 0.5-1.0 cm. Then, the sliced fruits were laid inside the basket in one layer. The basket was placed into UNO, an in-house mobile dryer that uses circulating air for removing moisture. The drying process takes 5-14 days to ensure the moisture content is below 10%. Dried fruits were kept in a screw cap plastic jar. The on-site observation of the dried fruits was carried out for approximately 3 months. Changes in colour, odour, and appearance were recorded.

Freezing Process

Ripe fruits were used in this technique. The outer parts of fruits were peeled off and seeds were removed by sieving, which left only the fleshes. The fleshes were stored in closed plastic containers and kept in a freezer at -10 to -18°C prior to the production of starting material for juice production.

The on-site observation of the dried fruits was carried out for approximately 3 months. Changes in colour, odour, and appearance were recorded.

Microbial Enumeration and Heavy Metal Analysis

Microbial enumeration and heavy metal contamination analyses were carried out at Natural Products Quality Control Laboratory, FRIM using methods as reported in Nurhazwani et al. (2015) and Norulaiman et al. (2011) and following British Pharmacopoeia 2016.

Nutritional Content Analysis

100 g of frozen *S. caseolaris* fruit fleshes were sent to Unipeq Laboratory, Universiti Kebangsaan Malaysia for determination of the essential nutrient groups in human dietary.

Oxygen Radical Antioxidant Capacity (ORAC) Test

ORAC test on frozen *S. caseolaris* fruit fleshes was carried out following Shalini et al. 2018.

RESULTS AND DISCUSSION

Only frozen *S. caseolaris* fruit fleshes were used for the following analyses due to the presence of mold in dried fruits after three months. This may be due to the drying *S. caseolaris* fruits using UNO mobile dryer is not suitable although, in the previous study (unreported), the dryer was able to dry carambola fruit successfully. To ensure that the frozen fruit fleshes have no microbial contamination, the sample of fruit fleshes was sent for a microbial test. Based on a study by Nazli & Hashim (2010), *S. caseolaris* is a potential phytoremediation species where it possesses the capacity to take up selected heavy metals via its root and store them in the leaves. Therefore, the heavy metal test was also carried out to determine the safety of the fruit. The results indicated that frozen fruit fleshes are safe for consumption and comply with the Drug Registration Guidance Document (DRGD), Ministry of Health Malaysia (Table 1).

Table 1 Microbial enumeration and heavy metals content of frozen *S. caseolaris* fruit fleshes

Test/heavy metal element	Result	Limit*	Interpretation
Total aerobic microbial count (TAMC)	<10 CFU/ml	5 x 10^4 CFU/ml	√
Total yeasts & moulds count (TYMC)	<10 CFU/ml	5 x 10^2 CFU/ml	√
Bile tolerant gram negative bacteria	<10 PN/ml	<10^2 PN/ml	√
Escherichia coli	Nil	Nil	√
Salmonella spp.	Nil	Nil	√
Lead (Pb)	0.07 mg/kg	NMT 10.0 mg/kg	√
Cadmium (Cd)	0.01 mg/kg	NMT 0.3 mg/kg	√
Mercury (Hg)	0.03 mg/kg	NMT 0.5 mg/kg	√
Arsenic (Ar)	0.03 mg/kg	NMT 5.0 mg/kg	√

CFU: colony form unit; PN: Probable number, NMT: Not more than
*Drug Registration Guidance Document (DRGD), Ministry of Health, Malaysia

From Table 2, by using the freezing technique, essential micronutrients such as vitamin C can be preserved and may contribute to vitamin C content in fruit juice. Energy and carbohydrate contents in Jus Laris are higher due to the addition of sugar during juice production (Nor Azah et al. 2020b). The loss of dietary fiber in Jus Laris compared to frozen fruit fleshes is due to the filtration process during fruit juice production in order to create a pleasant drinking experience (Nor Azah et al. 2020b).

ORAC assay is a tool to measure antioxidant capacity based on the quantity of vitamin E analogue that is also known as trolox. This assay is very useful to determine the antioxidant activity of a product that has multiple compounds that contribute to synergism activity. ORAC value has been used widely to determine the antioxidant activity of food products (Prior & Cao 2000). Table 3 showed antioxidant activity for frozen *S. caseolaris* fruit fleshes. The value is considered as good antioxidant activity as the recommended daily dosage is in the range of 3500 to 5000 ORAC units per day (Prior & Cao 2000). This supports several reports documented that the fruits possess high antioxidant activity (Dewanto et al. 2018; Nor Azah et al. 2020a).

Table 2 Comparison of nutritional content of 100 g of frozen *S. caseolaris* fruit fleshes and 100ml of Jus Laris based on Nor Azah et al. 2020b

Parameter	**Result**	
	100g of frozen *S. caseolaris* fruit fleshes	100ml of Jus Laris based on Nor Azah et al. 2020b
Energy (kcal)	25 (105kJ)	50 (210kJ)
Protein (g)	0.5	0.2
Total fat (g)	<0.1	<0.1
Carbohydrate (g)	5.8	12.4
Ash (g)	0.5	0.3
Moisture (g)	93.2 g	87.1
Total sugar		
• Fructose (g)	Not detected	4.2
• Glucose (g)	Not detected	4.0
Dietary fibre (g)	7.7	0.8
Vitamin C (ascorbic acid) (mg)	5.2	0.55

Table 3 Antioxidant activity of frozen *S. caseolaris* fruit fleshes

Sample	**ORAC value (µmol TE/100g)**
Frozen *S. caseolaris* fruit fleshes	5,000±800

Based on the results from this study, freezing *S. caseolaris*'s ripe fruit fleshes that have been processed prior to fruit juice production at a commercial scale, will help to maintain the sustainability of fruit supply throughout the year. This technique will enable the PIFWA community to collect the fruits or outsource to other mangrove forest areas than Sungai Acheh, Nibong Tebal, Pulau Pinang. Different regions in Malaysia may affect the flowering and fruiting season of *S. caseolaris*, reported by Noraliza et al. (2020), *S. caseolaris* in Southern Malaysia flowers in December, and the size of the fruits may fetch up to 10 cm in diameter.

CONCLUSION

Freezing is the best technique for preserving fruits before processing them into starting materials for commercial-scale juice production. This project is still ongoing, therefore the final quality of fruit juices from commercial scale production needs to be analysed for their quality and safety.

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PRODUCTION OF READY-TO-DRINK (RTD) APPLE MANGROVE (*SONNERATIA CASEOLARIS)*

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Sonneratia caseolaris (L.) Engl. from the Lythraceae family is known as berembang (Malay) and pidada or perapat laut (Sabah). Traditionally, its sour young fruits have been used for flavouring while the semi-ripe fruit juice is used for treating cough. A community in Kampung Sungai Acheh, Pulau Pinang had consumed the fruits in raw form with condiments or turned them into fruit jam. FRIM and Penang Inshore Fishermen Welfare Association (PIFWA) had developed LARIS, a ready-to-drink (RTD) from *S. caseolaris* fruits. In order to produce LARIS on a commercial scale, a large number of fruits are required, and since *S. caseolaris* is not a vegetable crop, it can be difficult to harvest abundant fruits. Therefore, FRIM had come up with a solution by using freeze processed fruit and fruit puree formulation. Finally, LARIS was produced at a facility certified with Good Manufacturing Practice (GMP) and has successfully obtained Halal certifications. Its labelling and packaging have also complied with the Food Regulations 1985 by the Ministry of Health. LARIS is listed as a product under PIFWA and has been currently made available for purchase through an online platform. In addition, LARIS had won several innovation awards; such as Si2TE 2019 (Gold medal), MTE 2020 (Silver medal), and Malaysia-Croatia Technology Exchange 2020 (International Award of Merit).

Keywords: *Sonneratia caseolaris*, ready-to-drink, fruit drink, product developmet, community

INTRODUCTION

Apple Mangrove or *Sonneratia caseolaris* (L.) Engl. belongs to the Lythraceae family. The species is known as berembang by the local people and associated the tree with fireflies where adult fireflies flash after the sun sets (Nada et al. 2009). The tree is distributed in tidal creeks and mangrove swamps of Malaysia, Indonesia, Thailand, Bangladesh, India, and Ceylon. The evergreen tree grows up to 8 m and can reach up to 20 m. The branches are horizontal, while the twig is slender with round and opposite leaves of 7 cm long. *S. caseolaris* has underground roots as well as pneumatophores and breathing roots (Bokshi et al. 2020). The genus *Sonneratia* is popularly known for its apple-shaped fruit. The mature fruits of *S. caseolaris* are edible. A mixture of ground leaves with raw rice is used to reduce body heat and relieve itchiness due to measles. The tree trunk can be used as firewood and poles. The villagers in Kampung Sungai Acheh, Pulau Pinang had utilised *S. caseolaris* fruits to be made into delicious jam.

FRIM has carried out a project together with Penang Inshore Fisherman Welfare Association (PIFWA) to expand the potential of *S. caseolaris* as a food and beverages (F&B) product. After three years of R&D, LARIS, a ready-to-drink (RTD) from *S. caseolaris* has been developed with scientific values through chemistry, bioactivity, formulation, sensory, and product safety studies. For commercialisation purposes, the processing procedure for handling delicate *S. caseolaris* fruits and formulation of fruit puree has been developed to ensure the sustainability of raw material supply.

MATERIALS AND METHODS

Plant Materials

Fruits of *Sonneratia caseolaris* were collected from the mangrove area in Kampung Sungai Acheh, Nibong Tebal Pulau Pinang with help from the fishermen's community. The plant specimen was prepared and identified by a FRIM botanist.

Preparation of Fruit Paste

The matured fruits were cleaned, peeled, cut into smaller pieces, and cooked in boiling water for a few minutes. The fleshes were sieved to separate the flesh from seed and fibrous parts. Only the fruit fleshes were stored in a refrigerator at 4°C until the amount of fruit flesh are enough to make fruit paste. The stored fruit flesh is known as fruit puree.

Once the amounts of fruit puree are sufficient (around 80–100 kg); fruit paste was prepared by cooking the fruit puree in water and sugar until turns into thick reddish-brown caramel. The ratio of fruit puree and sugar is 1:1.

Formulation of Ready-To-Drinks (RTD)

Formulation of apple mangrove RTD was carried out in Formulation Laboratory, FRIM. To ensure the formulation is safe and of good quality, RTD had undergone several experiments: antioxidant evaluation, cytotoxicity tests, stability, safety, nutritional content determination, and consumer acceptance tests. All tests were conducted at Natural Product Division except for nutritional content, the formulated RTD was sent to UNIPEQ, UKM.

Production of Apple Mangrove RTD

To penetrate the market, apple mangrove RTD must be manufactured in Good Manufacturing Practice (GMP) facility. The cleanliness and confidentiality of final products from the GMP facility were trustworthy. The products must comply with labelling regulation by *Bahagian Kawalan Kualiti Makanan* (BKKM), from Ministry of Health (MOH). In addition, any product with halal certification can attract more consumers in Malaysia especially.

RESULTS AND DISCUSSION

More than 100kg of matured *S. caseolaris* fruits in form of fruit puree were collected from December 2019 to the end of January 2020. From these fruit purees, a total of 70 kg of fruit paste were successfully prepared for the production of apple mangrove RTD using a formulation developed in FRIM. Ruza Marketing Sdn Bhd in Kulim, Kedah was selected as the manufacturer since their facility is equipped with Good Manufacturing Practices (GMP) and Halal certifications. The formulated RTD is named LARIS (Figure 1) as a part of the scientific name for apple mangroves. LARIS also carried out meaning ‘be in demand’ or ‘selling’ in Malay. The catchy name is easy to remember and good for marketing purposes.

In order to ensure the quality and safety of LARIS, microbial contamination tests and heavy metal analysis were carried out as described by Norulaiman et al. (2011) and Nurhazwani et al. (2015). Based on the results in Tables 1 and 2, LARIS complies with MOH regulations for F&B products.

Figure 1 LARIS, apple mangrove RTD

Table 1 Microbial contamination result

Test	Result	Criteria British Pharmacopeia, 2019
Total aerobic microbial count (TAMC)	1.5 x 10^4 CFU/ml	5 x 10^4 CFU/ml
Total yeasts & moulds count (TYMC)	1.3 x 10^1 CFU/ml	5 x 10^2 CFU/ml
Bile tolerant gram negative bacteria	<10 PN/ml	<10^2 CFU/ml
Escherichia coli	Absent	Absent
Salmonella spp.	Absent	Absent

Table 2 Heavy metal analyses result

ELEMENT	Result (mg/kg)	Criteria DRGD 2016; REV JAN 2019.
Plumbum (Pb)	<0.01	NMT 10.0 mg/kg
Cadmium (Cd)	<0.01	NMT 0.3 mg/kg
Mercury (Hg)	<0.01	NMT 0.5 mg/kg
Arsenic (Ar)	<0.01	NMT 5.0 mg/kg

DRDG= Drug Registration Guidance Document

The oxygen radical absorbance capacity (ORAC) assay is used to evaluate the antioxidant activity of LARIS. ORAC has been widely used to determine the antioxidant capacity of food, beverages, and natural products because the assay can measure inhibition of time and degree into a single quantity (Cao & Prior 1999). The antioxidant capacity of LARIS (Table 3) may be contributed by the presence of flavonoids in fruit as mentioned by Saidatul Husni et al. (2016). Nutritional content analysis was carried out at UNIPEQ UKM and the result is shown in Table 4. This nutritional information is included in the label as requested by BKKM, MOH.

Table 3 Antioxidant evaluation on LARIS

Sampel	ORAC value (µmol TE/100 ml)
LARIS	1000 ± 100

TE= trolox; an analogue vitamin E, equivalent

Table 4 Nutritional content of apple mangrove RTD, LARIS

Parameter	Result
Energy (kcal/g/100ml)	49 kcal (206 kJ)
Protein (g/100ml)	0.01 g
Total Fat (g/100ml)	0.07 g
Carbohydrate (g/100ml)	12.1 g
Ash (g/100ml)	0.12 g
Moisture (g/100ml)	87.7 g
Total Sugar (g/100ml)	7.5
• Fructose	3.6
• Glucose	3.2
• Sucrose	0.7
Dietary Fiber (g/100ml)	<0.1
Vitamin C (mg/100ml)	5.3

Cytotoxicity tests were carried out on human liver (WRL-68) and African green monkey kidney (Vero) cell lines. Based on figure 2, at a concentration of 10% (v/v), LARIS did not show dose-response for both cell lines compared to water. This indicates that LARIS is considered non-cytotoxic.

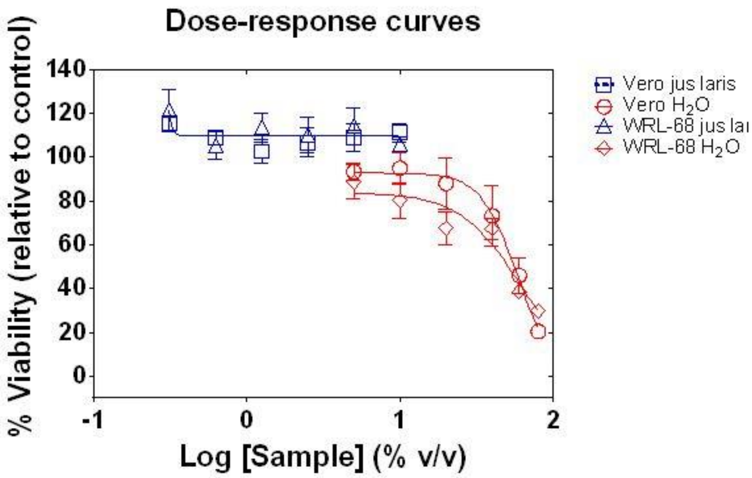

Figure 2 Dose-response curve of LARIS after 24 hours exposure on WRL-48 and Vero cell lines

A consumer acceptance test was conducted by observing LARIS's organoleptic properties. Nine (9) human subjects were given LARIS to drink and answer the questionnaire. The result showed in table 5. Most subjects liked the sourness and sweetness taste in LARIS. Seven out of nine subjects found that the colour of the product was acceptable. All subjects liked and can accept the aroma of the product.

Table 5 Organoleptic observation by human subjects

Category	**Characteristics**	**Scale**		
		1	2	3
Taste	Sour		4	5
	Sweet	3	2	4
	After taste	1	4	4
Appearance	Concentration	1	4	4
	Colour	1	7	1
Aroma			6	3

3: like, 2: acceptable, 1: do not like

CONCLUSION

LARIS, RTD from apple mangrove has big potential to be commercialised and promoted as a tourism product, especially for mangrove areas. Formulation of fruit puree and fruit paste, prior manufacturing process in the factory, supports and allows LARIS to be produced at a commercial scale despite the scarcity of fruit. Through a tight R&D and quality control process, LARIS's quality and safety can be maintained.

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DOCUMENTATION ON TRADITIONAL KNOWLEDGE OF ORANG ASLI FROM SUB-ETHNICS ORANG KUALA, ORANG SELETAR, MAH MERI AND REPLICATE OF BATEQ & TEMUAN SUB-ETHNICS IN PENINSULAR MALAYSIA

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Forest Research Institute Malaysia (FRIM) has conducted traditional knowledge (TK) documentation on medicinal plants used by the orang asli in Peninsular Malaysia since the 9th Malaysia Plan (MP). Under the 9th MP and 10th MP, 15 out of the 18 sub-ethnics from 14 locations were involved in this project. Replication of documentation for three sub-ethnics in different locations was also carried out during the 10th MP namely, for Semelai, Jahai, and Temiar. Meanwhile, documentation involving three additional sub-ethnics which are Mah Meri (2016), Orang Kuala (2017), Orang Seletar (2017), and two sub-ethnics replicates namely Bateq (2018) and Temuan (2018) were subsequently conducted by FRIM TK team under the 11th MP. The study aimed to enrich TK database on medicinal plants used by the orang asli as well as to validate their traditional claims. A wide range of activities was carried out in this study, namely conducting a rapid rural appraisal, holding a workshop on raising awareness, obtaining prior informed consent (PIC), socio-economics household survey, capacity building on documentation among the orang asli communities, database development, and laboratory analyses of selected medicinal plants. Under the 11th MP, a total of 481 medicinal plant samples (289 species) were recorded. Of the 481 medicinal plants recorded, 125 medicinal plants (113 species) were from Mah Meri sub-ethnic, 73 medicinal plants (69 species) from Orang Kuala sub-ethnic, 72 medicinal plants (62 species) from Orang Seletar sub-ethnic, 71 medicinal plants (68 species) from Bateq sub-ethnic and 140 medicinal plants (125 species) from Temuan sub-ethnic. Twenty one selected species were collected in bulk and brought to FRIM laboratories for phytochemical and bioactivities screening. The results showed that 15 out of 21 species were considered to have multiple bioactivities potentials and can be suggested for further evaluation.

Keywords: Traditional knowledge, orang asli, documentation, medicinal plants

INTRODUCTION

Medicinal plants had been used by the orang asli for decades to treat various kinds of illness and also for healing purposes. Orang asli inherited traditional knowledge (TK) of medicinal plants from their ancestors orally via daily practices such as stories, legends, folklore, rituals, songs, dances, poetry, and customary laws (Intan Nurulhani et al. 2009). Most of the older generation still retained their knowledge, while some of their TK have fallen into disuse or been forgotten. In Malaysia, documentation of traditional knowledge of medicinal plants among the orang asli tribe is still scanty (Mohd Raznan et al. 2021). Maryati (2016) also mentioned that TK of Malaysian indigenous people was not well documented, unlike TK of the Chinese and Indians. Therefore, effort in documenting TK of medicinal plants used by the orang asli is crucial and needed immediately before TK is further lost or eroded.

Forest Research Institute Malaysia (FRIM) has taken the responsibility for implementing TK of orang asli documentation since 2007. Fifteen orang asli sub-ethnics from 14 locations were involved in this documentation project from the 9th Malaysia Plan (MP) until the 10th MP namely Semelai, Jahai, Temiar, Semai, Temuan, Jahut, Jakun, Bateq, Semoq Beri, Che Wong, Orang Kanaq, Lanoh, Mendriq, Kensiu, and Kintak. In 2015, FRIM managed to replicate 3 studies of the same sub-ethnics involving the Semelai, Jahai, and Temiar in different locations. To complete the documentation on medicinal plants among the 18 sub-ethnics of orang asli in Peninsular Malaysia, FRIM extended the documentation effort to include the three remaining sub-ethnics (Mah Meri, Orang Kuala, and Orang Seletar), mostly residing at the seaside in the 11th MP. Besides, two additional replicate studies have been carried out for Bateq and Temuan sub-ethnics. To date, FRIM has successfully documented 18 and 5 replications of orang asli sub-ethnics in 22 locations.

MATERIALS AND METHODS

This study was conducted from 2016 until 2018 involving five sub-ethnics (Mah Meri, Orang Kuala, Orang Seletar, Bateq, and Temuan) in five different locations. Details of the study conducted are shown in Table 1. Figure 1 shows the distribution of the four study sites in Selangor, Pahang, Negeri Sembilan, and Johor.

Figure 1 Location of study sites

Table 1 Details of study conducted

No	Subethnic	Year	Location
1	Mah Meri	2016	Kampung Orang Asli Bukit Bangkong, Sepang, Selangor
2	Orang Kuala	2017	Kampung Sri Pantai, Batu Pahat, Johor
3	Orang Seletar	2017	Kampung Simpang Arang, Gelang Patah, Johor
4	Bateq (Replicate)	2018	Kampung Sungai Berjuang, Jerantut, Pahang
5	Temuan (Replicate)	2018	Kampung Dusun Kubor, Jelebu, Negeri Sembilan

This study was conducted using a comprehensive approach involving a wide range of activities during documenting and recording of the orang asli's knowledge following a similar methodology by Lim et al. (2015). The first activity is conducting rapid rural appraisal (RRA) by gathering basic information on the uses and knowledge of medicinal plants by sub-ethnics. This is followed by communication with the Department of Orang Asli Development (JAKOA) to have a better understanding of the community's lifestyle aspects such as socio-economic, education, and culture. The team also made several visits to meet the community leader/ batin/ penghulu to explain the project and TK-related issues. Further discussion was also conducted among the community involved especially knowledgeable persons such as traditional practitioners, bomoh, mid-wives, and puyang.

The second activity is holding a TK awareness workshop at the community level with permission from JAKOA after engaging with the leaders and medicinal plant experts of the community. During the workshop, the community was briefed about the Convention on Biodiversity (CBD), the National Policy on Biological Diversity, the current project, the importance of TK documentation, and issues regarding TK. The communities also participated and share their views on the project during the dialogue session.

The next activity is obtaining prior informed consent (PIC) and socio-economic household survey, in line with CBD, PIC from the local community before their knowledge sharing. The content of PIC was explained to the respondents before the socioeconomic household survey was conducted. During the survey, information on socioeconomics background and TK regarding the use of medicinal plants were recorded.

The final activity involving the community is TK documentation training and specimen collection which are conducted in two phases. A second PIC was obtained from those participating in the TK documentation training. Each phase of training was attended by at least 16 selected participants, comprising practitioners, TK experts, men, women, and youths. Participants were taught how to collect, document, and prepare the herbarium specimens scientifically. Plant samples were collected from nearby forests, bushes, villages, and some also from cultivation. During TK documentation training, selected plant species were collected and brought to FRIM laboratories for phytochemical and bioactivities screening i.e. antioxidant, anti-inflammatory, antidiabetic, antimicrobial, anticancer, and cytotoxicity. The plant herbarium specimens were identified by botanists using available keys and descriptions from various flora manuscripts and references. Information gathered from the training on medicinal plants and their usage was also recorded and uploaded to TK Botanical Research and Management Herbarium System (BRAHMS), FRIM.

RESULTS AND DISCUSSION

A total of 481 specimens were recorded from five sub-ethnics involved in this study. Of these, 457 specimens were identified to the species level. The taxonomic composition of medicinal plants in this study comprises 91 families, 223 genera, and 281 species. Table 2 shows the details of plant species recorded from each sub-ethnic. The Temuan and Mah Meri sub-ethnics recorded a higher number of collections; comprising 140 medicinal plants (125 species) and 125 medicinal plants (113 species) respectively, followed by Orang Kuala with 73 medicinal plants (69 species), Bateq with 71 medicinal plants (68 species) and Orang Seletar with 72 medicinal plants (62 species). The findings indicated that the knowledge of medicinal plants used among the five sub-ethnics is still rich.

From the documentation, it was noted that the orang asli utilised medicinal plants either from the wild or cultivated and most often both. The highest collection of wild species among the five sub-ethnics is Bateq 82%, followed by Temuan (66%), Orang Seletar (57%), and the lowest by sub-ethnics Mah Meri (32%) and Orang Kuala (32%). This result showed that Bateq and Temuan sub-ethnics were still heavily dependent on the forests or bushes nearby their village for medicinal purposes. Meanwhile, the Orang Seletar sub-ethnic was highly dependent on the plants sought from the mangrove areas for medicinal purposes, as their settlement is located nearby coastal/mangrove areas and their livelihood is dependent on the sea. On the other hand, the Mah Meri and Orang Kuala sub-ethnics are noted to be less dependent on the forest as their settlement are located near the coastal area and their livelihood is heavily dependent on the sea. However, they are still literally connected with the forest and still engaged in planting a small number of herbal plants in their backyards for medicinal purposes.

Table 2 Number of specimens and species by sub-ethnic

No	Sub-ethnic	Number of herbarium specimen	Number of species	Plants status	
				Wild (%)	Planted (%)
1	Mah Meri	125	113	43 (34%)	82 (66%)
2	Orang Kuala	73	69	23 (32%)	50 (68%)
3	Orang Seletar	72	62	41 (57%)	31 (43%)
4	Bateq (Replicate)	71	68	58 (82%)	13 (18%)
5	Temuan (Replicate)	140	125	92 (66%)	48 (34%)

From the study conducted, the five top families with the most species that were utilised by the five sub-ethnics were from the Zingiberaceae, ginger family represented by 20 species (6.9%), followed by Fabaceae, bean family (6.3%), Rubiaceae, coffee family (4.9%), Euphorbiaceae, spurge family (3.5%) and Rutaceae, citrus family (3.5%), as in Table 3.

Table 3 Largest family and percentage

No	Largest Family	Number of species	Percentage (%)
1	Zingiberaceae	20	6.9
2	Fabaceae	18	6.3
3	Rubiaceae	14	4.9
4	Euphorbiaceae	10	3.5
5	Rutaceae	10	3.5

A total of 21 selected species were collected and brought to FRIM laboratories for phytochemical and bioactivities screening. Fifteen (15) out of 21 species screened showed multiple bioactivities potentials (Table 4).

Table 4 Number of species undergo phytochemical and bioactivities screening

No	Sub-ethnic	Number of species	Number of potential species
1	Mah Meri	5	4
2	Orang Kuala	5	3
3	Orang Seletar	5	3
4	Bateq (Replicate)	3	3
5	Temuan (Replicate)	3	2
Total		**21**	**15**

CONCLUSION

Based on the findings, 481 medicinal plants were recorded from the five sub-ethnics, comprising 91 families, 223 genera, and 281 species. The Temuan and Mah Meri sub-ethnics recorded a higher number of collections comprising 140 medicinal plants (125 species) and 125 medicinal plants (113 species) respectively; followed by Orang Kuala with 73 medicinal plants (69 species), Bateq with 71 medicinal plants (68 species) and Orang Seletar with 72 medicinal plants (62 species). A total of 15 species were recorded to have multiple bioactivities potentials and can be suggested for further evaluation. These new records have directly augmented and enriched FRIM TK database.

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INVENTORIES OF SELECTED POTENTIAL MEDICINAL PLANTS BASED ON TRADITIONAL KNOWLEDGE OF ORANG ASLI IN FOREST RESERVES

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As a continuation activity from the Traditional Knowledge (TK) documentation effort towards commercialization, a number of forest inventories of selected potential medicinal plant species used by orang asli were conducted. Currently, there are 2,452 herbarium specimens prepared by orang asli from theTK documentation project being deposited in TK herbarium, FRIM. A total of 677 species were used by the 18 orang asli sub-ethnics in 22 locations (inclusive of 5 replications of sub-ethnics). Other than documentation activity, 103 medicinal plants were selected for chemical and biological screening. In 2015, 21 species were discovered to have the potential of more than three (3) bioactivities which include anti-microbe, anti-oxidant, anti-inflammatory, anti-diabetic, and anti-cancer. However, the number of potential species gradually increased to 37 in 2018 based on results from laboratory analyses. A number of prototype products also were developed from these selected 37 species — as a way forward for commercialisation. To support the commercialisation of the potential selected species, the availability of their resources also needs to be surveyed. Subsequently, this leads to several inventories of the 37 potential plant species in 15 locations nearby orang asli villages: involving 19 forest reserves in different states in Peninsular Malaysia. An inventory exercise is involved setting up a minimum of 20 plots with 20 m X 10 m sized in each location. Collection of herbarium specimens and photographs of the plants were captured during the activity, which will be used as references in plant identification. Other than the collection of germplasm for *ex-situ* conservation, efforts were also geared towards plant propagation and tissue culture activities including a soil study.

Keywords: Inventories, medicinal plants, traditional knowledge

INTRODUCTION

The traditional knowledge (TK) documentation project was initiated back in the 9th Malaysian Plan, which aimed to document medicinal plants used by the orang asli in Peninsular Malaysia scientifically. According to the Department of Orang Asli Development (JAKOA), there are 18 sub-ethnics of orang asli in Peninsular Malaysia. The 18 sub-ethnics were further divided into three main groups, namely Proto Malay, Senoi, and Negrito. Other than documentation effort, laboratory analyses comprised of chemical and biological screening activities on selected medicinal plants were also conducted to reconfirm sub-ethnics claims on the uses and medicinal values of plants; despite exploring and discovering their new medicinal potentials. The whole project activities conducted by Forest Research Institute Malaysia (FRIM) indirectly indicated Malaysia's commitment as a party to the Convention on Biological Diversity (CBD 1992) and towards the implementation of the Nagoya Protocol on Access to Genetic Resources and the Fair and Equitable Sharing of Benefits Arising from Their Utilisation.

To date, a total of 18 sub-ethnics and 5 replications of similar sub-ethnics of orang asli from 22 locations in different states were involved in this project. A socio-economic survey was conducted among the head of households comprising 1,275 respondents to gauge and gather their knowledge and information related to medicinal plants used in treating common illnesses, as well as to keep them remain healthy. Based on information gathered from the survey, documentation of medicinal plants used was conducted at the local level. Currently, there are 2,452 herbarium specimens prepared by orang asli participants involved in the documentation activities were deposited in TK herbarium, FRIM. Of the total 677 species, 103 plant samples were subjected to chemical and biological screening (Intan Nurulhani et al. 2019).

Based on early laboratory findings, a total of 37 species were discovered to have the potential of more than three (3) bioactivities, which include anti-microbe, anti-oxidant, anti-inflammatory, anti-diabetic, and anti-cancer. A few prototype products were also developed from selected plant species as a way forward for commercialization. To support the commercialization potential of the selected species, the availability of their resources needs to be surveyed. Subsequently, this leads to an inventory of these 37 potential medicinal plants in the selected forest reserves. Efforts were also geared toward the collection of germplasm for plant propagation, tissue culture studies as well as *ex-situ* conservation. A soil study was also conducted to better understand the soil profile of the selected inventory sites. However, this paper will only focus on the inventory findings.

MATERIALS AND METHODS

There are three main stages involved in conducting medicinal plants inventory i.e., before, during, and post inventory. Proper preparation before an inventory activity is important to ensure that all activities proceed as planned. Basic procedure to enter the forest reserves i.e., an application of permit from forestry department is required, before selection of sites, basic needs and tools for inventory are prepared. The selection of sites to be inventoried depends highly on the nearby forests used by selected orang asli sub-ethnics to collect their sources of medicinal plants. Usually, a site visit was conducted first to get basic information on the forest site and to make sure the inventory conducted falls within the selected forest reserved as stated in the approved permit.

To protect the knowledge of these potential plants from misuse and misappropriation before commercialisation can take off; all team members including orang asli are required to sign a Non-Disclosure Agreement (NDA). Each of these 37 potential plants species is assigned with a specific code based on their habit, i.e., tree (T), shrub (S), climber (C), fern (F), ginger (G), and herbs (H) to facilitate data entry during an inventory activity. A minimum of 20 plots, with the size of 20 m X 100 m (20 sub-plots) was randomly set up based on the forest types (Wan Mohd Shukri et al. 2021). The inventory team comprises a leader, 2 botanists, and a few field assistants; each member is designated with several tasks. The leader will lead the team to set up the plot at the designated location while the botanists will conduct a survey and plant identification within the plot. The species spotted will then be pinpointed to the assistants for capturing plants photograph, plant collection for germplasm and herbarium, and also recording information (e.g., dbh, diameter, and number of individuals) for every plant found in the plot. Several orang asli from the villages nearby is hired to guide and assist the team on site. Botanists will identify these 37 species using the 'onsite plants identification guide' and confirm the identity of the seedlings and distinguish closely related species with the assistance of the orang asli experts or practitioners. The diameter size of every individual species found in the plot was measured using DBH tape and calipers. The plant samples collected were not only used as a reference for plant identification and ex-situ conservation, but it was also used as a germplasm material for plant propagation and tissue culture activities. Soil samples from the selected plots also were collected for soil study.

RESULTS AND DISCUSSION

In 2015, a pilot inventory exercise has been conducted in Bera Forest Reserve (FR). During the 11th Malaysia Plan (2016-2020), FRIM received funding from KeTSA (formerly known as KATS) to conduct an inventory project related to potential medicinal plants in selected forest reserves. The number of potential species gradually increased from 21 in 2015 to 23 in 2016, and from 33 in 2017 to 37 between 2018 – 2019; based on the laboratory results. The sources of TK of these 37 species came from the 15 orang asli sub-ethnics. In total, it involved 15 locations within 19 forest reserves–in seven states, namely Pahang, Johor, Kedah, Perak, Terengganu, Kelantan, and Selangor (Figure 1).

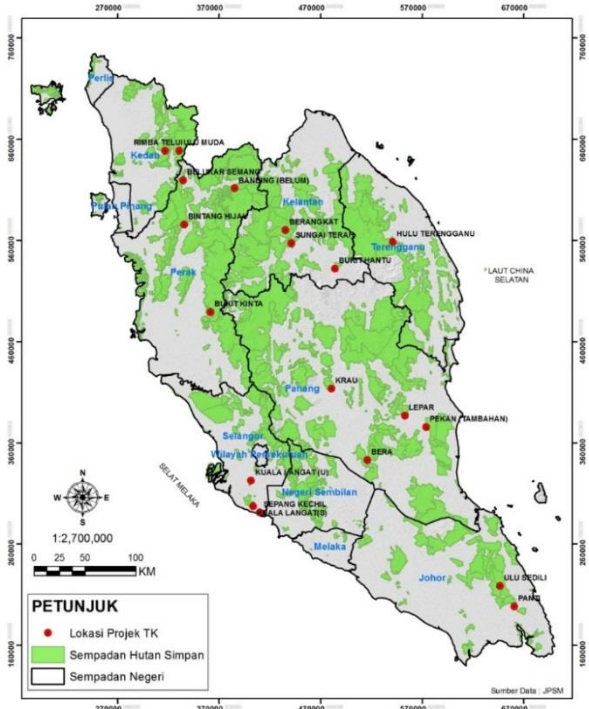

Figure 1 Inventory sites of selected forest reserves in Peninsular Malaysia

The number of plants recorded depends highly on the forest type, altitude, and habitat of each potential plant species. A total of 49,691 individuals were recorded (Table 1) during activities. The highest number of individual plants discovered was in Belukar Semang FR, Gerik, Perak with a total of 6,519 followed by Kuala Langat Utara FR, Banting, Selangor with a sum of 5,424 individuals. Meanwhile, the lowest number with only 929 individuals was recorded in Krau FR, Temerloh, Pahang.

The highest number of potential species discovered was in Panti FR, Kota Tinggi, Johor, with 17 out of 23 species (74%). It is followed by Bukit Kinta FR, Gopeng, Perak with 20 out of 33 species recorded (61%). The Kuala Langat Selatan & Sepang Kechil FR, Sepang, Selangor recorded the lowest number, i.e., with only 8% out of 37 potential species, compared to the other forest types. The Kuala Langat Selatan & Sepang Kechil FR, Sepang, Selangor consists of peat swamp and mangrove forests and as such, lead to the discovery of different species with 3 out of 37 species recorded. Even though the discovery showed the lowest species recorded in these FR, a higher number of individuals involving 5,312 trees were recorded. Out of 37 potential species, only 34 species were recorded in various plots. Three other species were found outside the inventory plots, which indicated that the distribution of species still exists. This also indicated that specific species are only present in certain habitats.

Table 1 Information on inventory site and species

No	Forest Reserve (FR)	Year	No. of potential species	No of species (%) discovered	Total individuals
1	Bera FR, Ramsar Site, Bera, Pahang	2015	21	10 (48%)	1,588
2	Pekan (Tambahan) FR & Lepar FR, Pekan, Pahang	2016	23	13 (57%)	3,401
3	Krau FR, Temerloh, Pahang			10 (43%)	929
4	Panti FR, Kota Tinggi, Johor			17 (74%)	3,367
5	Ulu Sedili FR, Kota Tinggi, Johor			12 (52%)	1,853
6	Ulu Muda & Rimba Telui FR, Baling, Kedah	2017	33	19 (58%)	4,654
7	Bukit Kinta FR, Gopeng, Perak			20 (61%)	1,705
8	Banding (Belum) FR, Gerak, Perak			18(55%)	3,783
9	Bintang Hijau FR, Gerik, Perak			14 (42%)	4,161
10	Belukar Semang FR, Gerik, Perak			17 (52%)	6,519
11	Hulu Terengganu FR, Kuala Berang, Terengganu	2018	37	21 (57%)	1,807
12	Berangkat & HS Sungai Terah FR, Gua Musang, Kelantan			22 (59%)	2,863
13	Bukit Hantu FR, Gua Musang, Kelantan			20 (54%)	2,325
14	Kuala Langat Utara FR, Banting, Selangor	2019		18 (49%)	5,424
15	Kuala Langat Selatan & Sepang Kechil FR, Sepang, Selangor			3 (8%)	5,312

Other than data and plant photographs, representative plant samples of each species found in every forest reserve were collected for herbarium specimens. These samples will be used as references and for plant identification purposes. A total of 34 samples representing 34 species found during inventories of selected forest reserves were collected with 487 duplicates and deposited in TK Herbarium, FRIM. In addition, a collection of 592 wildings from 28 species was also conducted for *ex-situ* conservation. To date, a total of 66 plants were planted in TK Garden located in Ethnobotanical Garden, FRIM, whereas the remaining plants were placed in FRIM's nursery. Selected plant species were also collected for plant propagation and tissue culture studies. Samples of soils were also collected from selected inventory sites for soil study and profiling.

CONCLUSION

Results from this study were obtained during the implementation of various inventories in selected forest reserves. Observations on potential plants species were also conducted during the inventory activities. As there are limitations with regard to time and number of plots compared to the actual area of the entire forest reserves, all inputs recorded, especially the number and the presence (existence) of species are based on limited findings and observations. Therefore, findings from this study cannot be used to generalize the exact existence or status of the said species in the forest reserves involved.

Data collection from this study will be used as future reference and guide in forest planning programmes including conservation, contract farming, forest plantation industries, and product development. Furthermore, the germplasm collection located in FRIM's nursery will be planted in Maran Research Station, as a germplasm project under the 12th Malaysia Plan. This activity will also be a continuous study, especially on plant propagation to ensure a sufficient source of raw materials; that can meet the market demand once the product has been commercialized. Besides creating a germplasm pool, the said project is also geared towards plant propagation studies to ensure quality planting materials.

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ACCESS AND BENEFIT SHARING (ABS) AGREEMENT: AN INITIATIVE TOWARDS FAIR AND EQUITABLE SHARING OF BENEFITS ARISING FROM UTILIZATION OF TRADITIONAL KNOWLEDGE ASSOCIATED WITH GENETIC RESOURCES

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Access and benefit sharing (ABS) is a legal framework under the Convention on Biological Diversity (CBD) and Nagoya Protocol that aims to fairly share benefits arising from genetic resources. As a party to CBD, Malaysia is committed to the fair and equitable sharing of benefits arising from the utilization of genetic resources, as well as the other two CBD's objectives, namely, conservation of biological diversity and sustainable use of natural resources. At the national level, the Access to Biological Resources and Benefit Sharing law 2017 (Act 795) has been enforced on 18th December 2020. Therefore, the practice of obtaining prior-informed consent (PIC) and developing ABS agreements or mutually agreed terms are also applied to traditional knowledge associated with medicinal plants research at FRIM. Traditional knowledge associated with medicinal plants provides valuable information regarding their traditional properties and their potential uses for pharmaceutical, herbal and cosmetic product development. Currently, FRIM has drafted three ABS agreements for research, development, and commercialisation (R, D & C) on three medicinal plants used by selected sub-ethnics of orang asli. Each ABS agreement involved three parties, namely the community as the traditional knowledge provider: the state authority as genetic resources provider/owner, and FRIM as the user or technology developer. The stakeholder consultation has been conducted and a series of negotiations and finalization of the ABS agreements with the selected sub-ethnic communities and state governments are still ongoing.

Keywords: Traditional knowledge, orang asli, medicinal plants, access and benefit sharing

INTRODUCTION

Malaysia is a signatory of the Convention of Biological Diversity (CBD) since 1994 and remains committed to achieving its objectives of (i) conserving biological diversity, (ii) using natural resources sustainably, and at the same time (iii) sharing benefits fairly and equitably arising from the use of genetic resources (CBD 1992). The third objective of CBD is further strengthened under the Nagoya Protocol (2010) on Access to Genetic Resources and the Fair and Equitable Sharing of Benefit Arising from their utilization (Nagoya Protocol 2011). At a national level, the law on Access to Biological

Resources and Benefit Sharing (Act 795) has been enacted in 2017 and enforced on 18th December 2020.

The concept of access and benefit sharing (ABS) refers to a set of principles related to how biological resources may be accessed, and how users and providers of biological resources and traditional knowledge agreed on the fair and equitable sharing of benefits that might arise from their utilization. In the case of accessing biological resources based on traditional knowledge of indigenous and local communities (ILCs), users are required to obtain permission or consent from the ILCs who owned the knowledge to use it and to share any benefits that result from its uses. Therefore, ABS is based on a prior informed consent (PIC) approach obtained from a provider of traditional knowledge and negotiation between both parties to develop mutually agreed terms (MAT), to ensure the so-called fair and equitable sharing of benefits arising from their utilization (Figure 1).

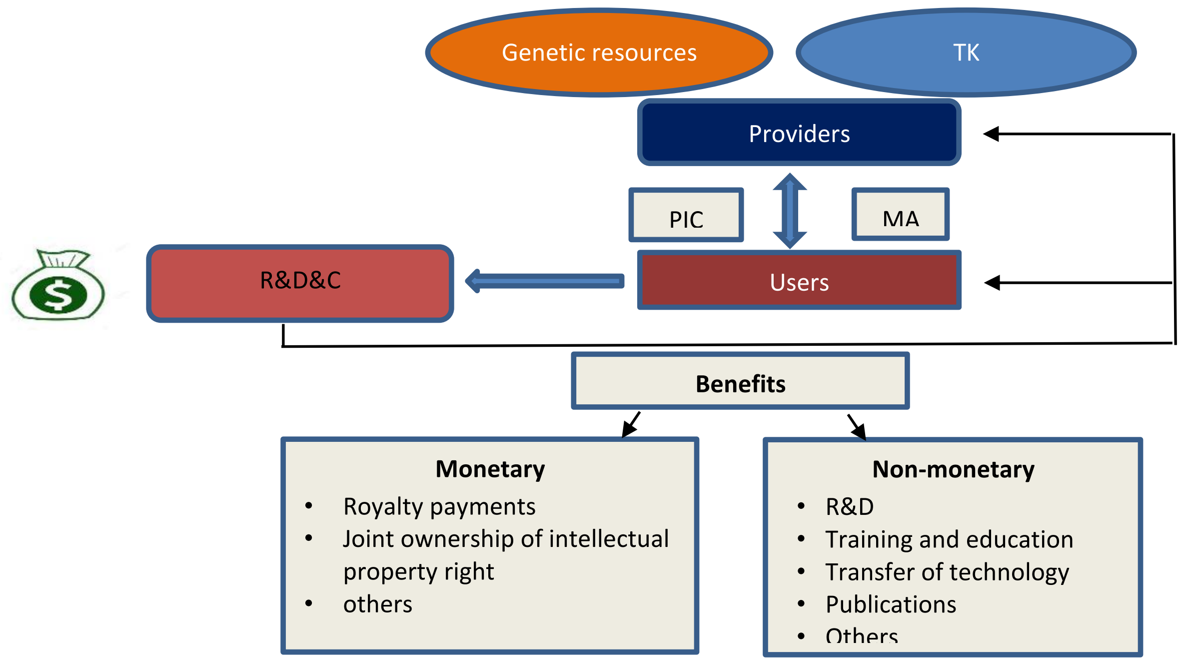

Figure 1 Access and Benefit Sharing principles. Provider—competent authority, private landowner, indigenous & local communities, User—researchers, universities, industries, TK—traditional knowledge, PIC—prior-informed consent, MAT—mutually agreed terms

MAT AND ABS AGREEMENT

Traditional knowledge associated with medicinal plants provides valuable information regarding their traditional properties and their potential uses for pharmaceutical, herbal and cosmetic product development. The practice of obtaining PIC from ILCs has been applied to research, development, and commercialisation (R, D & C) of traditional knowledge associated with medicinal plants at the Forest Research Institute Malaysia (FRIM) since 2007.

Currently, FRIM is in the process of developing MAT or ABS agreements. FRIM has drafted three ABS agreements for R, D & C on three medicinal plants used by selected sub-ethnics of orang asli, namely UGG0064, KLL092, and ABP016, respectively. Each ABS agreement involved three parties, namely the community as the traditional knowledge provider: the state authority as genetic resources provider/owner, and FRIM as the user or technology developer.

The drafting process has started back in 2016. The early discussion to develop MAT and ABS agreement template was carried out with the Semelai subethnic, at RPS Iskandar, Bera, Pahang, i.e., the first community involved in the FRIM's TK documentation project. MAT and ABS agreement template was further improved via stakeholder consultation that was organised on 14th February 2017. In the stakeholder consultation, representatives of communities, non-government organisations, universities, researchers, and government agencies were involved. MAT and ABS agreement template has been developed during the stakeholder consultation and was then further discussed with the selected orang asli sub-ethnics communities and state governments. A series of negotiations were conducted with selected sub-ethnic communities (Table 1) to ensure the comprehensiveness of the said ABS agreement and not to mention the benefits that will be shared equitably and in a fair manner.

Since Act 975 was enforced in 2020 and the ABS Guidelines were just established in 2021 (KeTSA, 2021), the ABS agreement template was further revised again accordingly. Therefore, a series of negotiations and finalization processes of the ABS agreements with the selected sub-ethnic communities and state governments are still ongoing.

Table 1 Negotiations on ABS agreement template with the selected sub-ethnics and state governments

No	Date	Orang asli communities/ state governments
1	22 March 2017	Semelai - RPS Iskandar, Tasik Bera, Pahang
2	23 March 2017	Semelai - Kg Sg Lui, Jempol, Negeri Sembilan
3	3 May 2017	Jahai & Temiar - RPS Banun, Gerik, Perak
4	3 May 2017	Lanoh - Kg Air Bah, Lawin, Perak
5	4 May 2017	Semai - Kg Ulu Geroh, Gopeng, Perak
6	23 May 2017	Kensiu - Kg Lubok Legong, Baling, Kedah
7	11 July 2017	Temiar - Pos Tuel, Lojing, Kelantan
8	12 July 2017	Mendriq - Kuala Lah, Gua Musang, Kelantan
9	13 July 2017	Semoq Beri - Kg Sg Berua, Kuala Berang, Terengganu
10	2 May 2018	Unit Perancangan Ekonomi Negeri (UPEN), Perak
11	23 May 2017 & 21 March 2021	Bahagian Perancangan Ekonomi (BPEN), Kedah

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PUSRAWI INTERNATIONAL COLLEGE OF MEDICAL SCIENCES (PICOMS) - PROVIDE SUPERVISORY SERVICES OF INDUSTRIAL AND CLINICAL TRAININGS TO DIPLOMA IN MEDICAL SCIENCE STUDENTS

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In 2016, the Natural Products Division (BHS) and the Pusrawi International College of Medical Sciences (PICOMS) signed a memorandum of understanding (MoU). The agreement aims to provide industrial training to final year students from PICOMS's Faculty of Health Sciences. The agreement has been renewed annually until it is terminated in 2019. For each session, students will receive seven weeks of industrial training. PICOMS students will be assigned to research laboratories in the Natural Products Division (BHS), FRIM, for this industrial training period. Students will learn about the techniques and tests conducted in medicinal plant research at FRIM, particularly investigations on the efficacy and toxicity of medicinal plants. Cell Signaling Laboratory and *In vivo* Research, Polysaccharide Research Laboratory, Bioactivity Laboratory, Biopesticide Laboratory, Product Formulation Laboratory, and FRIM Research Station in Maran are among the laboratories that provided industrial training programme. A total of 567 students have completed the industrial training at FRIM during six years programme. BHS, FRIM, and PICOMS have benefited greatly from the collaboration. BHS obtained manpower resources and made a profit of RM 170, 100 from student fees (Figure 1). Meanwhile, PICOMS had the option to place students in research laboratories with full facilities, giving them experience in research activities, particularly those involving medicinal plants.

Keywords: PICOMS, supervisory services, industrial training, clinical training

INTRODUCTION

Pusrawi International College of Medical Sciences (PICOMS) is a local private university college located in Taman Batu Muda, Batu Caves, Selangor. The university college offers 21 programmes in various fields. The Health Science Program is one of the programmes that are offered to students. Health Science is a field related to human health and one of the studies involved was the study on herbs and their uses for human health.

The Natural Products Division (BHS) has signed a memorandum of understanding (MoU) with PICOMS in 2016. The agreement was continued and renewed year after year until its termination in

2019. The main purpose of the MoU is to provide supervision on industrial and clinical training to diploma students from PICOMS.

Such collaborations provide an opportunity for PICOMS students to undergo training in laboratories that conducted studies on herbal efficacy and toxicity. Among the laboratories involved are Cell Signaling Laboratory and In Vivo Research (MISIV), Polysaccharide Research Laboratory, Bioactivity Laboratory, Biopesticide Laboratory, Product Formulation Laboratory, FRIM Research Station at Maran, and other laboratories under BHS.

To date, a total of 567 PICOMS students have undergone industrial training at BHS (Figure 2). BHS has successfully provided initial exposure to PICOMS students about their future careers in herbal and health sciences. Figure 3 shows different careers path that have been pursued by the former students who have undergone industrial training at BHS, FRIM.

OBJECTIVES

Through this collaboration, BHS, FRIM agreed to provide industrial training to final year students from the Faculty of Health Sciences PICOMS. This collaboration enables PICOMS students to learn the techniques and tests conducted in herbal research at FRIM, especially on the efficacy and toxicity studies of herbs.

STUDENT INFORMATION AND ANALYSIS

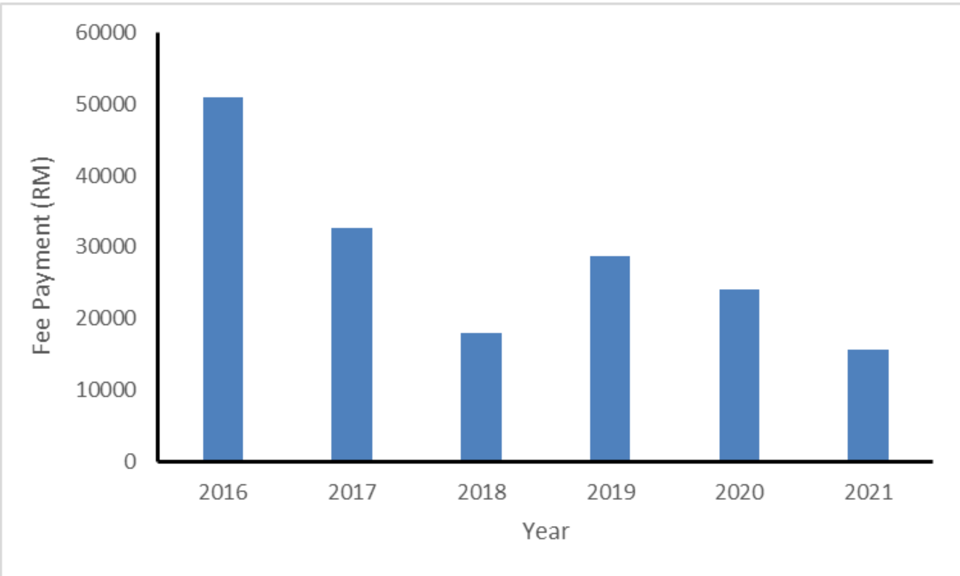

Figure 1 Payment of fees received from PICOMS. The total payment is RM 170,100

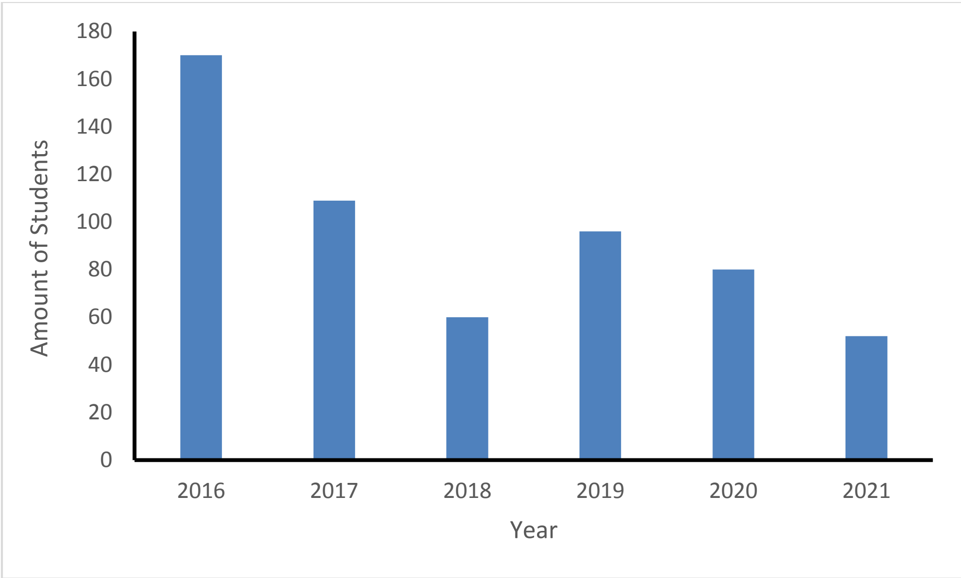

Figure 2 Number of PICOMS students at FRIM each year from 2016 to 2021

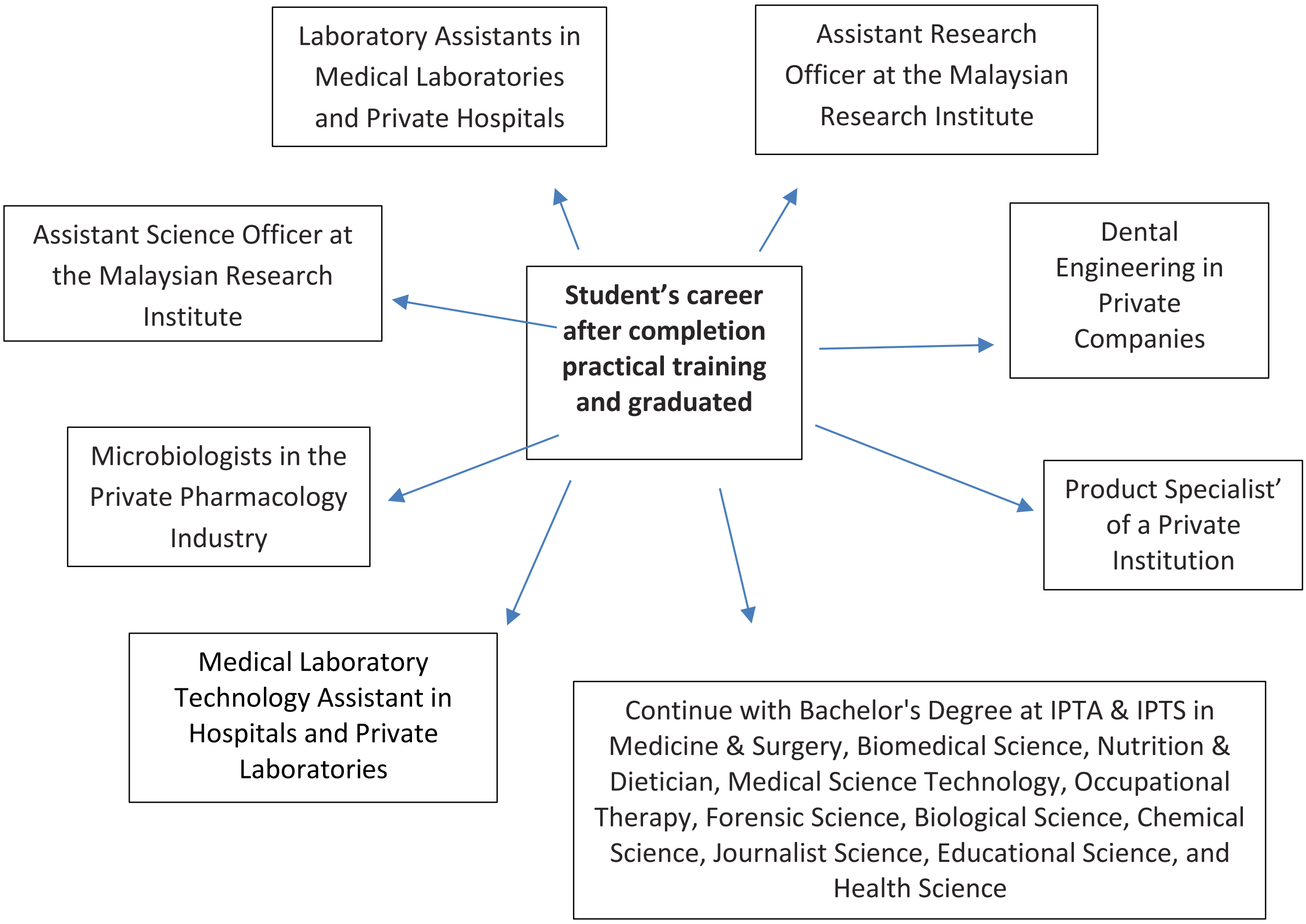

Figure 3 Careers pursued by students after completing the internship and graduation from 2016 to 2019. Data obtained from interviews of former students who underwent internships at FRIM

CONCLUSION

The cooperation between BHS and PICOMS has provided many benefits to both parties. BHS received manpower resources and profit generation from fees charged to students. On the other hands, PICOMS has attained the best place for students to undergo industrial training.

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