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Editor–in–Chief's Message

I am delighted to be the editor-in-chief of the volume 3 of the Journal of the Dry Zone Agriculture, which is published by Faculty of Agriculture, University of Jaffna. Faculty of Agriculture was established in 1990 in Kilinochchi and underwent several displacements and finally it has settled in its own location of Kilinochchi in 2014. Education without innovative research and development is meaningless for the community so the faculty decided to publish a Journal named as Journal of Dry Zone Agriculture (JDZA). The objective of JDZA is to publish peer reviewed, high-quality research papers and the Volume 1 was released in 2012 while faculty was functioning at Jaffna. Due the shifting and resettlement, the faculty was unable to continue to release the journal annually as planned. At present the faculty is well settled at Ariviyal Nagar, Kilinochchi with adequate infrastructure and human resources, so the faculty has decided to recommence the publication of the JDZA. The volumes 2, 3 and 4 will be released in 2018 and I am proud to function as the Editor in chief for Volumes 2 and 3.

JDZA is a multidisciplinary, peer-reviewed journal that publishes original research in dry zone agriculture and other associated fields. The JDZA provides platform to publish the research work of the students, scholars and academicians. Our primary role as editors is to encourage the best work to be submitted and to manage a fair process of review. All submissions will be subjected to the journal's well-established system of peer review, which is rigorous and expeditious. We are determined not to compromise on our publication policies to our contributors to maintain the quality of the JDZA.

Volume 3 of JDZA is compiled with six papers which were subjected to the journal's double-blind review process. I would like to hear your valuable suggestions on improving our journal further. I sincerely extend my thanks to the contributors, editorial board members and reviewers and I am looking forward for your continuous support. I offer my profound thanks to the co-editors and the members of the editorial board who contributed towards the quality publication of the JDZA.

Dr.(Mrs.) S. Sivachandiran
Editor−in−Chief

Co–Editors' Message

We are delighted to celebrate the launch of Volume 3 of the Journal of Dry Zone Agriculture (JDZA), at the Fourth International Conference on Dry Zone Agriculture (ICDA 2018) on 1st and 2nd of November, 2018 published by the Faculty of Agriculture, University of Jaffna, Sri Lanka. The JDZA is a multidisciplinary, peer-reviewed journal that publishes original research articles especially on dry zone agriculture and on the associated fields such as Agronomy, Animal production, Plant protection, Soil chemistry, Food science, Agriculture economics and extension, Agriculture engineering, Crop modelling and statistics, Plant physiology, Weed science, Forestry and Agroforestry, etc.

In the Globe, dry lands cover more than 40 % of the world's land surface and are home to one-third of the global population while, In Sri Lanka, it covers almost three quarters (70 %) of the island's land surface. Characteristics of dry zone are expressed by climates, soils and other relief such as peneplain, bi-model rainfall pattern and predominant soil of reddish brown earth. Despite the regular patterns of these ecological conditions, Sri Lanka faces severe flood in Southern sites while prolonged drought with unexpected rainfall in North and East parts of the country for last five years. Consequently, it leads to various threats and challenges on crops and livestock production. Rather than adapting development strategies, establishing Climate Resource Centre in a region is vital to achieve the sustainable development goals by practicing Climate Smart Agriculture in dry land areas. Selection of crops and breeds, and their effective management, practices that maintain and enrich the soil fertility are key steps forwarded.

We extend our sincere thanks to the authors for their submission of research articles and the reviewers for their timely response and for their critical assessments on the manuscripts and valuable comments. The recommencement of the release of JDZA is a joint venture of several key personnel within and outside the faculty. The credit goes to the Editorial Committee of JDZA, the Dean of the faculty of Agriculture, Staff of the Faculty of Agriculture, Organizing committees of ICDA 2015 and 2016 for their untiring support in releasing the journal in time as planned on the 1st day of ICDA 2018. We are confident that the future editorial committees also follow the tradition of releasing JDZA in the first day of ICDA in forthcoming years. We wish to thank the Vice Chancellor of University of Jaffna and the University administration for granting the financial assistance from the University Research Grant to release the journal. Quality is the important aspects of any final product which will be assessed by the consumers. This credit goes to Harikannan Printers and we wish to record of sincere thanks to them for their editing and attractive printing in time.

We are also happy to launch the website for the Faculty Journal at www.jdza.jfn.ac.lk and this website is linked with the faculty homepage: http://www.agri.jfn.ac.lk/.The editorial committee urges the research community to publish original research articles related to dry zone agriculture and other related fields in the future volumes of JDZA as hard copy or as soft copy to the email of jdzajournal@gmail.com.

We look forward to welcoming your submissions to the forthcoming volumes.

Jeyavanan, K. & Venugoban, K.
Co−Editors

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Diversity, Distribution and Biomass of Tree Community in a Tropical Dry Forest of Northern Sri Lanka

Thirukkumaran, S., Jeyavanan, K.* and Sivachandiran, S.

Department of Agronomy, Faculty of Agriculture, University of Jaffna, Kilinochchi, Sri Lanka

Abstract: A study was conducted in a tropical dry forest in Northern Province of Sri Lanka. The study aims to assess the tree diversity, distribution and carbon stock. Field assessment was conducted in six sites of the state forest, namely *Kulamurippu*-A, *Kulamurippu*-B, Puthukudiyirupu, *Nagansolai*, *Andankulam* and *Theravil*. Sampling plots were randomly selected from each location at a size of 20 m × 20 m with three replicates. Samples were collected and herbarium specimens were prepared and submitted to the National Herbarium, Royal Botanical Garden, Peradeniya for species identification. Indices of Shannon−Wiener, evenness, species richness and IVI were used to assess the diversity and dominance of the species. Height and diameter of trees were measured to estimate biomass and carbon stock by using a tropical allometric equation. A total of 321 trees, comprising 31 species and six lianas from 20 families, were enumerated. The most representative family was ebenaceae with three species. The evaluated community presents an average density of 446 trees ha^{-1} and a basal area of 0.13 $m^2 ha^{-1}$. The based on the Importance Value Index (IVI), the forest was dominated by *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm. (39.42 %), *Manilkara hexandra* (Roxb.) Dubard (38.19 %), followed by *Chloroxylon* swietenia DC (27.88 %), *Diospyros ebenum* Koenig (25.38 %). and *Vitex altissimamilla* L. f. (24.39 %). These five species account for 155.26 % of IVI. Mean Shannon diversity index and evenness were 1.94±0.11 and 0.91±0.01, respectively. This suggested that tree species were equally distributed with medium species diversity compared to wet forest. Mean carbon stock of the forest reserve was 206.34±19.12 Mg C ha^{-1}, which was higher than other dry zone forests (92.62 Mg C ha^{-1}) and lower than wet zone forest (336.8 Mg ha^{-1}) in Sri Lanka. According to the IUCN red listed data, identified species were recorded as vulnerable (VU), near threaten (NT), endangered (EN), and least conservation (LC). Results of this study provide baseline information for formulation of conservation and management guidelines of forest ecosystems in the region.

Keywords: Diversity indices, Dry zone, IVI, Prevalence, State forest, Tropical forest

* Corresponding author email : *kjvanan@gmail.com* (K. Jeyavanan)

Introduction

Forests provide a wealth of material outputs of subsistence or commercial value includes provisioning of goods, protection, supporting and cultural services due its rich diversity of species. In dry forest of Sri Lanka, most of the genera are represented by a single species and have high taxonomic diversity (MOE, 2012). The forest cover has remained intact largely despite the conflict in the past three decades (SI, 2017). The extent of forest cover is 168, 120 ha (64 %) of land area in the Mullaitivu district, of which 2,108 was deforested due severe logging during 1992 to 2010 (UNREDD, 2014; SI, 2017). A forest reserve in the district which includes dense, open, plantation and mangrove forest. The forest vegetation play many roles in the district for economic development and environmental conservation of the district. Therefore, understanding the tree species composition, diversity, and structure is a vital instrument in assessing sustainability of the forest in terms of conservation and management of the ecosystems (Madoffe, 2006; Addo-Fordjour, 2009).

Under the present scenario of global climate change and increasing deforestation rates, it has become crucial to quantify the carbon stocks and fluxes particularly in the tropics (Houghton, 2005). Natural forests store a large quantity of carbon, and there is currently great interest in assessing that quantity accurately, as forests are cleared the carbon is converted to carbon dioxide in the atmosphere. The average aboveground biomass for dry zone forests was 92.62 Mg ha^{-1} and the wet zone estimates was 336.8 Mg ha^{-1} (Sinharajah) (Kumarathunge, 2009). There is also a great deal of enthusiasm among our people to conserve the biodiversity of this country (MOE, 2012). However, little information available on flora species and carbon stock in the Mullaitivu district. Therefore a study was carried out with the objectives of identifying the flora species and quantifying carbon stock of different forests reserve in Mullaitivu district.

2. Materials and Methods

2.1 Study Sites

This study was carried out in the multiple sites of the forest reserve in Mullaitivu district and it is a dry forest in northern Sri Lanka. The district Mullaitivu is divided into two ranges as Mullaitivu and Olumadu. For the study, there were six location namely *Nagancholai* (NS), *Kulamurippu* (A) (KUA), *Kulamurippu* (B) (KUB), *Therawil* (TW), *Puthukudiyirupu* (PK) and *Andankulam* (AU) selected from Mullaitivu range of forest reserve which is identified by Department of Forest as protected areas. Locations of *Kulamurippu* (A), *Kulamurippu* (B) are sited under different divisional secretariat divisions of Maritimepattu and Oddusuddan, respectively. Secondary data of extent, types, range, beats and free landmines areas were collected from the Forest Department of Sri Lanka to identify the reserved forest in the Mullaitivu District. Three sample plots (20 m × 20 m) were selected randomly from each site for the assessment.

Figure 1: Sampling location in the forest reserve in Mullaitvu district (Source: Google map, 2018, SI, 2017)

2.2 Diversity of Species

The species were identified in the field with the help of local guiders and community people who are living near the forest reserve. Preliminary identification was done by experts with digital photo graphs for each specimens. Specimens of leaves, flowers and fruits of the species were collected and preserved based on the guidelines developed for herbarium preparation. Further, samples specimens of each species were submitted to the Department of National Botanical Gardens, Peradeniya for further identification at species levels. Diversity of the species was assessed by using Shannon−Wiener Index (SWI) (Shannon and Weaver, 1949) denoted by;

$$H = -\sum[(pi \times ln\,(pi)]$$

∑= summation, pi = proportion of total sample represented by species i , S = species richness, Hmax = ln(S) maximum diversity possible, E = evenness (= H/Hmax, (H: 1.5 - 3.5) (Pielou, 197; Yue *et al.* 2004). The value of H represents species heterogeneity and can be classified into low (H' < 1.5), medium (1.5–3.5) and high (H' > 3.5) (Pambudi and Rahayu, 2017). Tree height and diameter were measured to estimate the above ground, below ground and carbon content of the forest. Height of the tree was measured by using a clinometer Suunto PM-5/360 PC for all the trees above 5 cm in diameter at breast height (dbh) in the sample plot (Lotfalian *et al.*, 2007). Measure the stem diameter of each tree at 1.3 m above the soil surface using a diameter tape 283D/5M (Hairiah *et al.*, 2001).

2.3 Important Value Index

In order to evaluate the horizontal structure of the species in the study community, we used the following structural variables: abundance, dominance, frequency, with which we calculated the Importance Value Index (IVI). Diameters at breast height and other data generated from this study were used to calculate the basal area and relative dominance. From the identified species, number of individuals in species and relative frequency. Relative density was calculated based on a species occurrence in study plot. Importance Value Index (IVI) was performed based relative frequency, relative density

and relative dominance (Gates, 1949; Curtis and Mc-Intosh, 1950; Misra and Puri, 1954; Curtis, 1951; Phillips, 1959; Misra, 1969; Mostacedo and Fredericksen, 2000; Müeller-Dombois and Ellenberg, 1974)

Relative density (RDe):

$$RDei = \left(\frac{Ai}{\sum Ai}\right) \times 100 = \frac{Density\ \ of\ a\ species}{Total\ density\ of\ all\ species} \times 100$$

or

$$RDei = \frac{Number\ of\ individuals\ of\ a\ species}{Total\ number\ of\ individuals\ of\ all\ species} \times 100$$

Where *RDei* is the relative abundance of species *i*=1…n, with respect to total abundance (*Ai*).

Relative dominance RDo:

$$RDoi = \left(\frac{Di}{\sum Di}\right) \times 100 = \frac{Basal\ area\ of\ a\ species}{Total\ basal\ area\ of\ all\ species} \times 100$$

Where, *RDoi* is the relative dominance of species i, with respect to total dominance (*Di*); Basal area is the stem cross sectional area at breast height of species i =1…n.

Relative frequency (Rf)

$$RFi = \left(\frac{Fi}{\sum Fi}\right) \times 100 = \frac{Frequency\ \ of\ a\ species}{Total\ frequancy\ of\ all\ species} \times 100$$

Where, *RFi* is the relative frequency of species *i* with respect to the total frequency (*Fi*); The Importance Value Index (*IVI*) is defined as:

$$IVI = \sum (RDei + RDoi + RFi$$

Where, *RDei* is the relative abundance; *RDoi* is the relative dominance, and *RFi* is the relative frequency. IV ranges between 0 - 300.

2.4 Biomass and Carbon Stock

Aboveground biomass (AGB) was calculated by using allometric equation (Chave *et al*., 2014).

$AGB=0.0673\times(\rho D^2 H)^{0.976}$

Where, AGB-Aboveground Biomass (kg tree^{-1}); ρ- wood density (gcm^{-3}), D-diameter at Brest height in cm, H-tree height in m. Belowground biomass (BGB) was calculated by using allometric equation developed for tropical forest by Cairns *et al*. (1997) is;

$BGB=\exp^{(-1.0587+0.8836 \ln (AGB))}$

Where, BGB= belowground root biomass in kg tree^{-1}, ln = natural logarithm, exp = "e to the power of". Sum of aboveground and belowground biomass was total biomass (TBM). The carbon stock was estimated only from woody living tree species from

the location except plant litter materials, broken or dieback tress, lianas, saplings and soil organic matters. The amount of the TBM estimation that had been acquired from the equation were converted to carbon stock of the single trees using conversion factor of 0.47 as suggested by IPCC (2006). Biomass and carbon stock were converted into Mg ha^{-1}. Total Carbon Stock (Mg C ha^{-1}) = TBM x 0.47. One way ANOVA test was done by using in SAS/STAT® 13.2 (SAS Institute Inc., Cary, NC, USA). Species diversity and other parameters were performed using Minitab® 17.3.0 (Minitab Inc, USA) and in Microsoft Excel (Microsoft Inc., Redmond, WA, USA). Kruskal Wallis was done to compare variables among the sites and Wilcoxon signed rank test was performed to find out the significance within one variables.

3. Results and Discussions

3.1 Diversity, Composition and Distributions of the Flora

A total number of 321 trees were assessed from 32 tree species and 18 families (Annex 1). In addition, there were six lianas species recorded and only two families of the species for lianas identified (Annex 2). Tree species richness was 32 in the forest reserve. Comparatively, species richness was increased with abundance of trees. Site Puthukudiyirupu (PU) had highest species richness and tree numbers than other sites (Table 1). Mean value of Shannon diversity index and evenness for the trees were 1.94 and 0.91, respectively and this showed that the forest had medium tree diversity and equally distributed among the study sites than other dry forest in Sri Lanka (Table 2). Evenness were not significantly differed among the study sites. The composition of species and plant families in secondary forests do not vary much with the forest type, their location and the abiotic conditions (Perera, 2012). Significantly, lowest tree diversity was recorded in the site *Kulamurippu* (KUB), with comparatively high species richness. Perera, (2012) reported that dry forests at comparatively high precipitation or soil moisture levels are richer in species and harbour more endemic species than the very dry areas of the island. Thus, the tropical seasonal forests are richer in species than the tropical semi-deciduous forests while northern lowland is richer in species than its eastern and southern counterparts.

According to the IUCN red listed data (MOE, 2012), species of five namely *Alseodaphne semicarpifolia* Nees., *Strychnos potatorum* L. f., *Chloroxylon swietenia* DC., *Dimocarpus gardneri* (Thw.) Leenh., *Manilkara hexandra* (Roxb.) Dubard. identified as vulnerable species (VU), four species of near threaten (NT) namely *Xylopia nigricans* Hook.f. & Thoms., *Diospyros affinis* Thw., *Memecylon petiolatum* Trimen ex Alston., *Vitex altissima milla* L. f., three species endangered (EN) namely *Diospyros ebenum* Koenig., Diospyros ebenoides Kosterm., *Xantolis tomentosa* (Roxb.) Raf. and eight species of least conservation (LC) namely *Polyalthia coffeoides* (Thw. ex Hook.f. & Thoms.) Thw., *Polyalthia korinti* (Dunal)

Table 1: Tree species abundance, richness, and diversity indices in different sites (1200 m^2)

Study sites	No. of Individuals	No. of Families	No. of genera	No. of species	SWI	Evenness
NS	56	10	10	12	2.29 ±(0.11)^{a}	0.94 ±(0.06)^{a}
KUA	54	10	11	15	2.06 ±(0.05)^{ab}	0.93 ±(0.01)^{a}
TW	54	10	10	13	2.03 ±(0.17)^{ab}	0.92 ±(0.01)^{a}
PK	58	13	14	21	1.96 ±(0.02)^{ab}	0.91±(0.06)^{a}
AK	47	11	14	16	1.76 ±(0.05)^{bc}	0.88±(0.01)^{a}
KUB	52	12	14	18	1.54 ±(0.18)^{c}	0.86 ±(0.06)^{a}
Total forest	321	18	21	32	1.94±(0.11)	0.91±(0.01)

Note: *Nagancholai* (NS), *Kulamurippu* (A) (KUA), *Kulamurippu* (B) (KUB), *Therawil* (TW), *Puthukudiyirupu* (PK) and *Andankulam* (AK): Values of SWI and Evenness were given with Mean ±SE. Mean with similar letters were not significant at p=0.01.

Thw., *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm., *Careya arborea* Roxb., *Memecylon umbellatum* Burm.f., *Atlantica ceylanica* (Am.) Oliver., *Micromelum minutum* (Forst. f.) Wight & Arn., *Dimocarpus longan* Lour., were recorded in the forest reserve. Among them, four species of *Xylopia nigricans* Hook.f. & Thoms., *Diospyros ebenoides* Kosterm., *Memecylon petiolatum* Trimen ex Alston., *Micromelum minutum* (Forst. f.) Wight & Arn. were recorded as endemic species. Sri Lanka has over 3,000 angiosperms from 214 families and 1,522 genera. Of these about a quarter are endemic (Seneratne, 2001). MALF (1995) reprothed that several valuable timber species such as satinwood (*Chloroxylon swietenia*), ebony (*Diospyros ebenum*), calamander (*Diospyros quaesita*) are also now listed as Endangered due to selective removal of mature trees. From the report of Dassanayake and Fosberg (1980−2004), 43 woody plants endemic to the country grow in the dry land of Sri Lanka. These include 26 tree, 2 liana and 15 shrub species.

3.2 Distribution of Trees Species

Occurrences of species was differed in the reserved forests. Table 2 provides a list of the five most dominant species in each study sites in the forest. Table 3 gives an information of relative density (RDe), relative frequency (Rf) and relative dominance (RDo) and importance value index (IVI) of trees in the whole forest reserve. Among the study sites, there were five dominant tree species had greater than 24 % of important value index (IVI) (Table 3) and these were *D. sepearia* (39.42 %), *Manilhara hexandra* (38.19 %), followed by *C. swietenia* (27.88 %), D. ebenum (25.38 %). and *V. altissimamilla* (24.39 %). However, in overall, all of this species were not found in a single location.

There were eight species such as *C. swietenia, D. affinis, D. ebenoides, D. ebenum, D. sepearia, Manilhara hexandra, Memecylon petiolatum,* and *V. altissima* milla common in all of these six locations (Annex 3). The Ebenaceae is most represented family with three species. The forest is comparatively wetted than other dry forest. Due to this, species of *Dimocarpus* and *Strychnos* were distributed in the study areas.

Table 2: Top five most abundant species in different sites based on important value index

Study Sites	Species
Site1 KU (B)	*Drypetes sepearia* (Wight & Arn.) Pax & Hoffm. (WERAI), *Manilkara hexandra* (Roxb.) Dubard (PALAI), *Xylopia nigricans* Hook.f. & Thoms (SEVINTHAI), *Diospyros ebenum* Koenig (KARUNGALI), *Vitex altissima milla* L. f. (KADDAMANAKU)
Site 2 PK	*Manilkara hexandra* (Roxb.) Dubard., *Vitex altissima milla* L. f.*Chloroxylon swietenia* DC (MUTHIRAI), THANNI THAMPARA, PAJIRI
Site 3 KU (A)	*Chloroxylon swietenia* DC., *Vitex altissima milla* L. f., *Xylopia nigricans* Hook.f. & Thoms., *Dimocarpus gardneri* (Thw.) Leenh. (MORRAI), *Diospyros ebenum* Koenig
Site 4 NS	*Chloroxylon swietenia* DC., *Pterospermum suberifolium* (L.) (VINNANKU), *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm., *Diospyros ebenum* Koenig, *Manilkara hexandra* (Roxb.) Dubard
Site 5 AK	*Drypetes sepearia* (Wight & Arn.) Pax & Hoffm., *Manilkara hexandra* (Roxb.) Dubard., *Diospyros ebenum* Koenig., *Schelechera oleosa* (Lour.) Oken (KOON), *Pterospermum suberifolium* (L.)
Site 6 TW	*Manilkara hexandra* (Roxb.) Dubard., *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm., *Chloroxylon swietenia* DC., *Vitex altissima milla* L. f., *Xylopia nigricans* Hook.f. & Thoms

Note: Note: *Kulamurippu* (B) (KUB), *Puthukudiyirupu* (PK), *Kulamurippu* (A) (KUA), *Nagansolai* (NS) *Andankulam* (AK) and *Therawil* (TW)

Alwis and Eriyagama, (1969) revealed that spatial heterogeneity in the soil moisture contents resulted in the formation of different forest communities which deviated from the typical *Manilkara hexandra-Chloroxylon swietenia-Drypetes sepiaria* community of lowland tropical seasonal forests in Sri Lanka. Even though, the forest is secondary origin (de Rosayro, 1961), high species richness and diversity was recorded in the district than other dry forest in Sri Lanka. Perea (2012) reported that Euphorbiaceae species are the most prominent in dry forest vegetation and their proportional abundance is high in areas where more harsh environments exist.

Table 3: Relative density (RDe), frequency (Rf) and dominance (RDo) with importance value index (IVI)

Species	RDe%	Rf%	RDo%	IVI
Drypetes sepearia (Wight & Arn.) Pax & Hoffm.	14.95	9.49	14.97	39.42
Manilkara hexandra (Roxb.) Dubard	10.90	8.86	18.43	38.19
Chloroxylon swietenia DC	9.03	7.59	11.25	27.88
Diospyros ebenum Koenig	5.30	8.23	11.86	25.38
Vitex altissima milla L. f.	5.92	7.59	10.88	24.39
Xylopia nigricans Hook.f. & Thoms	8.41	6.96	2.83	18.20
Pterospermum suberifolium (L.) Willd.	5.92	5.06	2.28	13.26
Memecylon petiolatum Trimen ex Alston	7.79	3.80	0.85	12.44
Xantolis tomentosa (Roxb.) Raf.	1.56	5.06	2.05	8.67
Alseodaphne semicarpifolia Nees	1.56	3.80	3.25	8.61
Dimocarpus gardneri (Thw.) Leenh.	1.87	3.80	2.55	8.22
Careya arborea Roxb.	2.18	1.90	1.79	5.87
PAJIRI	1.56	1.90	2.23	5.69
Berrya cordifolia (Willd.) Burret	2.80	1.90	0.90	5.60
Diospyros ebenoides Kosterm	3.74	1.27	0.18	5.18
Polyalthia korinti (Dunal) Thw.	0.62	3.80	0.22	4.64
THANNITHAMPARA	1.87	1.90	0.87	4.64
Schelechera oleosa (Lour.) Oken	0.31	0.63	3.35	4.29
Polyalthia coffeoides (Thw. ex Hook.f. & Thoms.) Thw.	0.93	2.53	0.52	3.99
SADAVAKKAI	1.25	1.27	1.12	3.63
Dimocarpus longan Lour.	0.62	1.27	1.19	3.08
Premna tomaentosa Willd.	0.62	1.27	0.57	2.46
Atlantica ceylanica (Am.) Oliver	1.25	0.63	0.51	2.39
Mesua ferrea L.	0.93	0.63	0.78	2.35
Bredelia retusa (L.) A. Juss.	0.62	1.27	0.38	2.27
Premna tomaentosa Willd.	0.62	0.63	0.86	2.12
Syzygium gardneri Thw.	0.62	0.63	0.40	1.66
IYAVAKAI	0.31	0.63	0.36	1.30

Drypetes sepiaria is a universally distributed species which dominates the forest understorey. *Manilhara hexandra* is also a unique species in the dry zone which dominate in dry areas but the species is either rare or absent in cooler and moist conditions. In comparatively wetter areas, a mixture of Annonaceae, Ebenaceae, Melastomataceae and Sapindaceae species tend to grow more frequently with some Euphorbiaceae, Rutaceae or Sapotaceae species. *Dimocarpus gardneri* and *D. longan* and *Strychnos minor* and *S. trichocalyx* grow in Kilinochchi forest which is comparatively wetter than the forests at Bundala.

3.3 Structure the Forest

Table 4 shows the structural characters, biomass and carbon stock in each study sites of the forest reserve. The forest reserve was distributed with a mean density of 446 trees ha^{-1}. The number of trees per unit area differed significantly among study sites (Table 4). PK site had the highest tree density of 484 trees ha^{-1}, followed by NS with 467 trees ha^{-1}. KUA and TW both had same density of 450 trees ha^{-1}. AK had the lowest tree density of 392 trees ha^{-1}. The mean DBH, basal area and carbon stock of the studied plots were 30.6 cm and 0.13 m^2 ha^{-1}, and 671.6 kg $tree^{-1}$, respectively. AK site had the largest stand basal areas, while KUB had the smallest basal areas. Mean carbon stock was high in AK and it was 1160.2 kg $tree^{-1}$ due to highest stand basal area recorded. Total basal area of the forest reserve was 48.88 m^2 ha^{-1}

Table 4: The structural attributes of the forest reserve in different sites in the district

Sites	Tree number	Density No ha^{-1}	Diameter (cm)	Height (m)	Carbon stock (kg $tree^{-1}$)	Basal Area m^2 ha^{-1}
Site1 KUB	52	433.33	29.6±2.4 (10−84)	9.3±0.6 (5−23)	545.7±146 (15−4902)	0.1±0.02 (0−0.8)
Site 2 PK	58	483.33	30.2±1.7 (7−62)	11.5±0.6 (5−21)	563.8±98.4 (8−3478)	0.12±0.01 (0.01−0.42)
Site 3 KUA	54	450	28.18±2.4 (1−111)	13±0.7 (5−24)	596±140 (9−6990)	0.12±0.03 (0.01−1.34)
Site 4 NS	56	466.67	30.7±1.8 (8−61)	13.8± 0.7 (5−24)	603.6±76.5 (12−2888)	0.12±0.01 (0.01−0.41)
Site 5 AK	47	391.67	35.1±3.8 (8−117)	13.2±0.7 (6−22)	1160.2±339 (11-12731)	0.21±0.05 (0.01−1.49)
Site 6 TW	54	450	30.4±1.9 (10−72)	12.8±0.6 (6−23)	638.8±130 (22−5213)	0.12±0.02 (0.01−0.57
Average	53.5	445.83	30.6±1 (7−117)	12.3±0.3 (5−24)	671.6±67.2 (8−12731)	0.13±0.01 (0.01−1.49)

Note: Note: *Kulamurippu* (B) (KUB), *Puthukudiyirupu* (PK), *Kulamurippu* (A) (KUA), *Nagansolai* (NS) *Andankulam* (AK) and *Therawil* (TW): Values of SWI and Evenness were given with Mean ±SE. Mean with similar letters were not significant at p=0.01.

Stem density of low land tropical forests at different sites was ranges from 535 to 522 stems ha^{-1} (Bandara *et al*., 2017). Total basal area of the two floodplain dry forests was ranges from 34.7 and 29.4 m^2 ha^{-1} in Mexican Tropical Dry Forest Landscapes (Jaramillo *et al.*, 2003)

3.4 Biomass and Carbon Stock

Mean values of the total biomass and carbon stock of the forest were 439 Mg ha^{-1} and 206 Mg C ha^{-1}, respectively. Comparatively, the site AK had a highest aboveground, belowground, and total biomass which were 462 Mg ha^{-1}, 79 Mg ha^{-1}, and 540 Mg ha^{-1}, respectively (Table 5). This was due to highest stand basal area recorded in AK site (Table 4). The AK location had highest aboveground, belowground and total carbon stock which were 217 Mg C ha^{-1}, 37 ±3 Mg C ha^{-1}, and 254 ±20 Mg C ha^{-1}, respectively (Table 5). Mean diameter and basal area of the AK was 30.4 cm and 0.21 m^2ha^{-1}, respectively. The site KUA had a significantly lowest biomass and carbon stock and were 364 Mg ha^{-1} and 171 Mg C ha^{-1}, respectively (Table 5). Mean diameter and basal area of the KUA was 28.18 cm and 0.12 m^2ha^{-1}, respectively (Table 4).

Table 5: Biomass and carbon stock of aboveground, belowground and total in the study sites

Sites	AGB	AGC	BGB	BGC	TB	TC
Site1:	368.45	173.17	64.29	30.22	432.74	203.39
KUB	±37.09^{ab}	±17.43^{ab}	±5.75^{ab}	±2.70^{ab}	±42.85^{ab}	±20.14^{ab}
Site2:	363.71	170.94	63.52	29.86	427.23	200.8
PK	±44.36^{ab}	±20.84^{ab}	±6.89^{ab}	±3.24^{ab}	±51.25^{ab}	±24.04^{ab}
Site3:	309.04	145.25	55.08	25.89	364.12	171.13
KUA	±18.04^{b}	±8.48^{b}	±2.84^{b}	±1.33^{b}	±20.89^{b}	± 9.81^{b}
Site4:	367.31	172.63	64.14	30.15	431.45	202.78
NS	±28.15^{ab}	±13.23^{ab}	±4.36^{ab}	±2.0^{ab}	±32.27^{ab}	±15.28^{ab}
Site5:	462.04	217.16	78.56	36.92	540.6	254.08
AK	±36.72^{a}	±17.27^{a}	±5.51^{a}	±2.59^{a}	±42.27^{a}	±19.86^{a}
Site6:	373.05	175.33	64.97	30.53	438.02	205.87
TW	±47.14^{ab}	±22.15^{ab}	±7.22^{ab}	±3.39^{ab}	±54.36^{ab}	±25.52^{ab}
Total Forest	373.9	175.74	65.1	30.6	439	206.34
	±20.1	±9.6	±3.1	±1.4	±23.2	±19.12

Note: *Kulamurippu* (B) (KUB), *Puthukudiyirupu* (PK), *Kulamurippu* (A) (KUA), *Nagansolai* (NS) *Andankulam* (AK) and *Therawil* (TW): Values of SWI and Evenness were given with Mean ±SE. Mean with similar letters were not significant at p=0.01. AGB: Aboveground biomass, AGC: Aboveground Carbon; BGB: Belowground biomass, BGC: Belowground; TB: Total biomass, TC: total carbon (Mega gram C^{-1} ha)

Prentice, (2001) shown that plant C density ranges from 120 to 194 Mg C ha^{-1} in tropical forests. In Sri Lanka, Kuruppuarachchi, (2011) reported that dry zone forest of Sigiriya sanctuary which the corresponding values of carbon stock is 77.0 Mg C ha^{-1}. The wet zone forest Udawattakele contained higher plant biomass C (249 Mg C ha^{-1}). Average carbon stock value from 1992 to 2010 is 153–162 Mg C ha^{-1} in dry monsoon forest which lower than low land rain forest ranges from 203–225 Mg C ha^{-1} (Mattsson, 2012) and Sinharajah rain forest, it was 336.8 Mg ha^{-1} (Kumarathunge, 2009).

Figure 2 shows that the relationship of carbon stock and tree height over diameter of the trees. Result of figure 2 (a) clearly indicated that carbon stock of a tree were increased with increasing rate over diameter of the trees. Figure 2 (b) shows that height of the tree was increased with deceasing rate over diameter of the trees. The forest was distributed with a mean height and diameter of 12.3 m and 30.6 cm, respectively (Table 4).

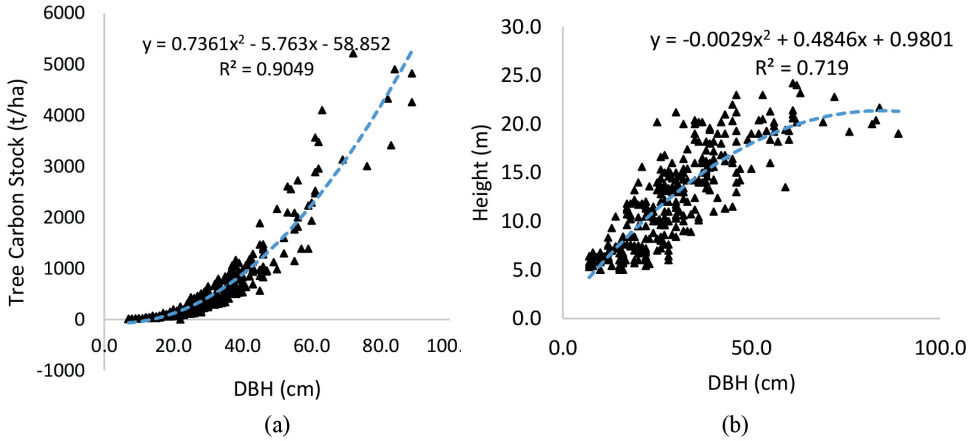


Figure 2: A dependent variables of tree carbon and height with independent variables of diameter class of the trees. (a) Tree carbon stock (kg tree^{-1}) vs. diameter (DBH); (b) tree height vs. diameter (DBH).

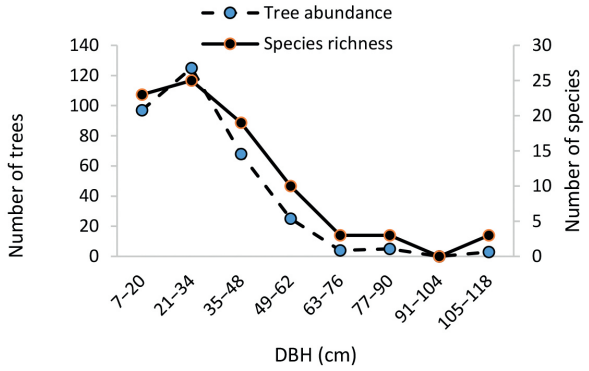
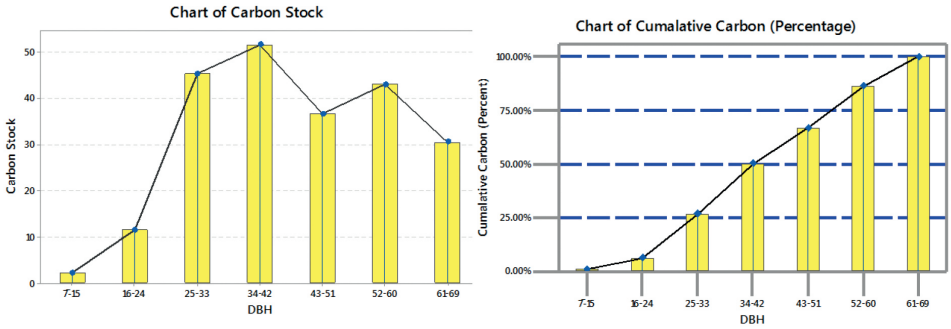


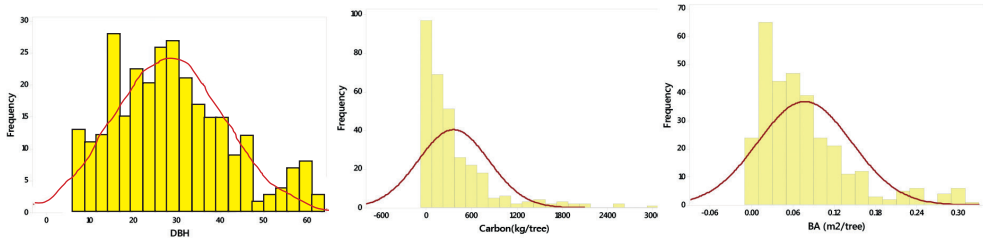
Figure 3: A dependent variables number of trees, species richness with independent variables of diameter class of the trees. Number of trees and species richness vs. diameter class (DBH)

Figure 3 shows that number of trees and species richness were left skewed and normally distributed with diameter of the tree at breast height (DBH). Figure 4 (a) shows that trees which falls between 34−42 cm diameter class had highest tree carbon which accounted more than 50 MgC ha^{-1}. More than 40 Mg C ha^{-1} of tree carbon stored by the diameter classes of 25−33,54−42 and 25−22 cm. Figure 3 and Figure 4 (b) illustrated that trees in the diameter classes >42 cm together had the lowest species richness (10 %) and abundance (8 %), yet contributed more than 50% of the total carbon stored in trees. Trees in the diameter classes >51 cm contributed to more than 75 % of the total carbon stored in trees.



(a) (b)

Figure 4: A dependent variables of tree carbon with independent variables of diameter class of the trees. (a) Tree carbon stock (MgC ha^{-1}) vs. diameter (DBH); (b) cumulative tree carbon stock (MgC ha^{-1}) vs. diameter (DBH)



(a) (b) (c)

Figure 5: A dependent variables of tree abundance (number of trees) with independent variables of diameter, carbon stock and basal area (a) Tree abundance vs. diameter (DBH, cm); (b) Tree abundance vs. carbon stock (kg tree^{-1}) and (c) Tree abundance vs. basal area (BA, m^{2}tree^{-1}).

Figure 5 shows the information about the class of diameter, carbon and basal area with number of trees. Figure 5 (b) and (c) illustrated that diameter class was normally distributed with tree abundance whereas carbon stock and basal area were right skewed . Figure 6 illustrated that that mean carbon stock and basal area were shows the similar trend among the species. The highest mean carbon stock was recorded

for *Manilhara hexandra* (876 kg tree^{-1}) and it was, followed by *Chloroxylon swietenia* (800 kg tree^{-1}). More than 10 tree species had greater than 300 kg carbon tree^{-1}. There were 5 species had the tree carbon between 300−200 kg tree^{-1}.

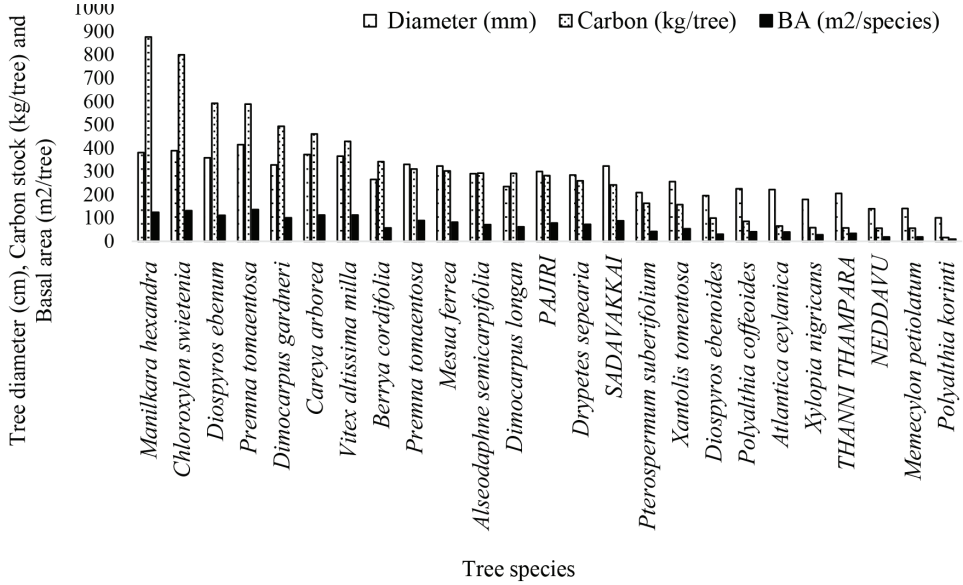


Figure 6: Mean diameter (cm), carbon stock (kg tree^{-1}), and basal area (m^{2}ha^{-1}) for tree species in the study sites.

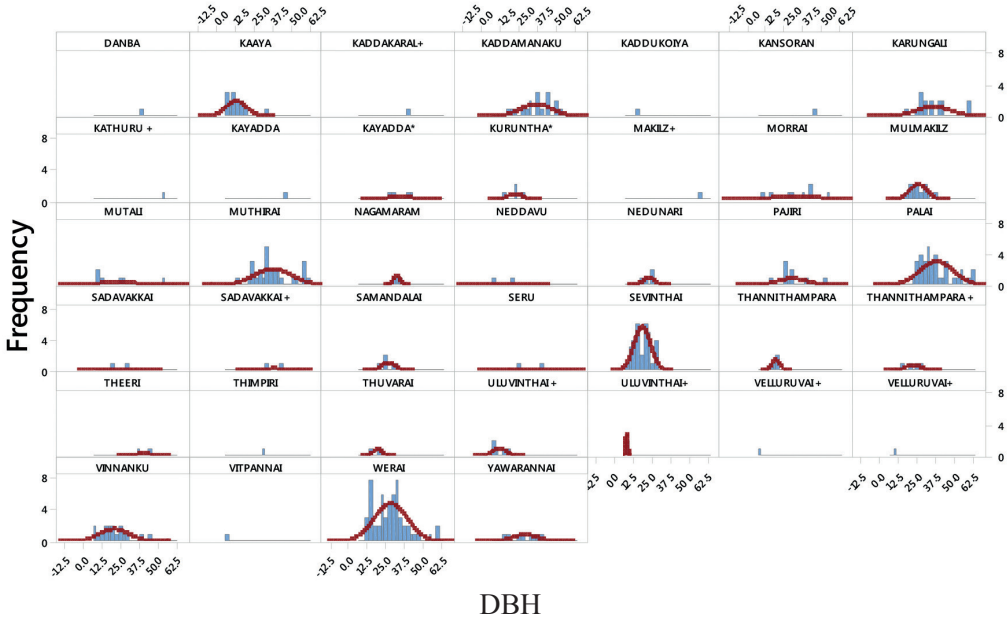


Figure 7: Number of individuals over diameter class distributions for tree species viewed individually. Botanical name of each species was given in annex 1.

Diameter of *Xylopia nigricans* (Sevintha) was well and normally distributed with other species of *Drypetes sepearia* (Weera), Thanni thampara, *Manilkara hexandra* (palai), *Pterospermum suberifolium* (vinnanku), *Diospyros ebenum* (karungali) in the study sites. Right skewed was observed in *Memecylon petiolatum* (Kaaya) less than 12.5 cm diameter while left skewed observed for *Chloroxylon swietenia* (muthirai) and *Vitex altissima milla* (kadamamnku) greater than 25 cm diameter. Highest frequency was recorded for Weerai followed by Sevinthai which falls between 12.5 5to 37.5 cm diameter class (Figure 7).

4. Conclusions

This study focuses the diversity, distribution and carbon stock of a dry forest in Northern Province of Sri Lanka. The forest had rich tree diversity and carbon stock compared to other n dry forest in the country. While species richness and abundance decreases with increasing diameter class, carbon storage increases with increasing diameter class. The selective preservation of certain species including relisted endanger species in the study sites are significantly important.

A total of 31 trees and six lianas species belongs to 20 families were recorded. The species were distributed equally with medium diversity. The forest was dominated by *Drypetes sepearia* (Wight & Arn.) Pax & Hoffm. Mean biomass and carbon stock of the forest reserve were 439 ± 41 and 206 ±19 Mg ha^{-1}, respectively. These findings provide baseline information about the forest structure, species composition and carbon stock for forest management plan.

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Annexure

Annex 1: Identified Tree Species in Mullaitivu Reserved Forest

Family	Scientific Name	Common Name	NCS
Annonaceae	*Polyalthia coffeoides* (Thw. ex Hook.f. & Thoms.) Thw.	NA (E), Nedunari (T), Omara (S)	LC
Annonaceae	*Polyalthia korinti* (Dunal) Thw.	NA (E), Uluvintai (T), Mi-Wenna (S)	LC
Annonaceae	*Xylopia nigricans* Hook.f. & Thoms	NA (E), See-Vindai (T), Heen-Kenda (S)	NT*
Clusiaceae	*Mesua ferrea* L.	Iron wood (E), Nagamaram (T), Naa (S)	
Ebenaceae	*Diospyros ebenum* Koenig	Ebony (E), Karunkali (T), Kaluwera (S)	EN
Ebenaceae	*Diospyros affinis* Thw.	NA (E), Karumpanicha (T), Eta-thimpiri (S)	NT
Ebenaceae	*Diospyros ebenoides* Kosterm	NA (E), Juwarai/ Thuwarai (T), NA (S)	EN*
Euphorbiaceae	*Drypetes sepearia* (Wight & Arn.) Pax & Hoffm.	Wera (E), Werai (T), Weera (S)	LC
Euphorbiaceae	*Bredelia retusa* (L.) A. Juss.	NA (E), Kaddakaral (T), Ketakaela (S)	
Fabaceae	UK	NA (E), Iyalvakai (T), NA (S)	
Lauraceae	*Alseodaphne semicarpifolia* Nees	NA (E), Yawarana (T), Wewarana (S)	VU
Lecythidaceae	*Careya arborea* Roxb.	NA (E), Kayadda (T), Kakadda (S)	LC
Loganiaceae	*Strychnos potatorum* L. f.	NA (E), Theen thukki (T), NA (S)	VU
Melastomataceae	*Memecylon petiolatum* Trimen ex Alston	NA (E), Kaaya (T), NA (S)	NT*
Melastomataceae	*Memecylon umbellatum* Burm.f.	NA (E), Pandi kaaya (T), Koora kaha (S)	LC
Myrataceae	*Syzygium gardneri* Thw.	NA (E), Nengal (T), Danba (S)	
Rubiaceae	UK	NA (E), Pajari (T), NA (S)	
Rutaceae	*Chloroxylon swietenia* DC	Satin wood (E), Muthirai (T), Brutha (S)	VU

Rutaceae	*Atlantica ceylanica* (Am.) Oliver	NA (E), Kurunthu (T), Yakinara (S)	LC
Rutaceae	*Micromelum minutum* (Forst. f.) Wight & Arn.	NA (E), Kakaipalai (T), Wal karapincha (S)	LC*
Sapindaceae	*Dimocarpus gardneri* (Thw.) Leenh.	NA (E), Morrai (T), Norrai (S)	VU
Sapindaceae	*Dimocarpus longan* Lour.	NA (E), Mutali (T), Rasa mora (S)	LC
Sapindaceae	*Schelechera oleosa* (Lour.) Oken	NA (E), Koolan (T), Koon (S)	
Sapotacea	*Manilkara hexandra* (Roxb.) Dubard	CeylonIron wood (E), Paalai (T), Palu (S)	VU
Sapotaceae	*Xantolis tomentosa* (Roxb.) Raf.	NA (E), Mulmakilz (T), NA (S)	EN
Sterculiaceae	*Pterospermum suberifolium* (L.) Willd.	NA (E), Vinnanku (T), Velank (S)	
Tiliaceae	*Berrya cordifolia* (Willd.) Burret	Trincomalle wood (E), Savandala (T), Halmilla (S)	
Verbenaceae	*Vitex altissima milla* L. f.	NA (E), Kaddamannaku (T), Milla (S)	NT
Verbenaceae	*Premna tomaentosa* Willd.	NA (E), Theeri (T), Seru (S)	
NA	UK	NA (E), Sadavakkai (T), NA (S)	
NA	UK	NA (E), Thanni thampara (T), NA (S)	

UK-Unknown, NA-Not available, NCS-National Conservation Status: LC-Least Concern, NT-Near Threatened, VU-Vulnerable, EN-Endangered

Annex 3: Occurrence of Species and Species Richness in each Sampling Sites

Scientific Name	KUB	PK	KUA	NS	AK	TW	Occurrence of sp.
Alseodaphne semicarpifolia Nees	√	√	×	×	×	√	3/6
Atlantica ceylanica (Am.) Oliver	√	×	×	×	×	×	1/6
Berrya cordifolia (Willd.) Burret	×	×	×	√	√	×	2/6
Bredelia retusa (L.) A. Juss.	√	√	×	×	×	×	2/6
Careya arborea Roxb.	×	√	√	×	×	×	2/6
Chloroxylon swietenia DC	√	√	√	√	√	√	6/6
Dimocarpus gardneri (Thw.) Leenh.	√	×	√	×	×	×	2/6
Dimocarpus longan Lour.	√	×	√	×	×	×	2/6
Diospyros affinis Thw.	√	√	√	√	√	√	6/6
Diospyros ebenoides Kosterm	√	√	√	√	√	√	6/6
Diospyros ebenum Koenig	√	√	√	√	√	√	6/6
Drypetes sepearia (Wight & Arn.) Pax & Hoffm.	√	√	√	√	√	√	6/6
Manilkara hexandra (Roxb.) Dubard	√	√	√	√	√	√	6/6
Memecylon petiolatum Trimen ex Alston	√	√	√	√	√	√	6/6
Memecylon umbellatum Burm.f.	×	√	×	×	×	√	2/6
Mesua ferrea L.	×	×	×	√	×	×	1/6
Micromelum minutum (Forst. f.) Wight & Arn.	√	×	×	×	×	×	1/6
Polyalthia coffeoides (Thw. ex Hook.f. & Thoms.) Thw.	×	×	√	×	√	×	2/6
Polyalthia korinti (Dunal) Thw.	×	√	×	×	×	√	2/6
Premna tomaentosa Willd.	×	√	×	×	√	×	3/6

Pterospermum suberifolium (L.) Willd.	√	√	×	√	√	√	5/6
Schelechera oleosa (Lour.) Oken	×	×	×	×	√	×	1/6
Strychnos potatorum L. f.	√	×	×	×	×	×	1/6
Syzygium gardneri Thw.	×	×	×	×	√	×	1/6
Vitex altissima milla L. f.	√	√	√	√	√	√	6/6
Xantolis tomentosa (Roxb.) Raf.	√	√	√	√	√	×	5/6
Xylopia nigricans Hook.f. & Thoms	√	√	×	×	√	√	4/6
UK	×	√	×	×	×	×	1/6
UK	×	√	√	×	×	×	2/6
UK	×	√	×	×	×	×	1/6
UK	×	√	×	×	×	×	1/6
Species richness	18/32	21/32	15/32	12/32	16/32	13/32	

Kulamurippu (B) (KUB), *Puthukudiyirupu* (PK), *Kulamurippu* (A) (KUA), *Nagansolai* (NS) and *Andankulam* (AK), *Therawil* (TW)

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Assessment of Morphological Characters of Selected Traditional Sri Lankan Rice Varieties (*Oryza sativa* L.)

Bandara, M.M.K.[1*], Herath, H.M.V.G.[2], Wickramasinghe, H.A.M.[2] and Bamunuarachchige, T.C.[3]

[1]Postgraduate Institute of Agriculture, University of Peradeniya, Sri Lanka
[2]Department of Agricultural Biology, Faculty of Agriculture, University of Peradeniya, Sri Lanka
[3]Department of Biological Sciences, Faculty of Applied Sciences, Rajarata University of Sri Lanka, Mihintale, Sri Lanka.

Abstract: Rice is the major food for more than half of the world population. Sri Lankan traditional rice varieties have a high genetic diversity and hence, a huge potential for important characters. A morphological study is the initial step towards genetic characterization. This study was aimed to evaluate the variability of selected Sri Lankan traditional rice varieties with respect to morphological characters. Seeds of 24 varieties and IR64 were selected for this study. A pot experiment with Complete Randomized Design (CRD) was used and five replicates were prepared. Fifteen characters were measured using standards published by IRRI. Principal component analysis (PCA) and single linkage cluster analysis were performed. Selected rice varieties were grouped into 5 clusters at 15 minimum distance level. Cluster I comprises twenty one varieties and other four clusters comprise single variety each. Varieties including *Goda heenati, Thawalu, Al wee, Goda el wee, Pachchaperumal, Godamanel, Goda wee, Kottiyaran, Kara el, Batapola el, Pokkali, Hetada wee, Moddai karuppan, Vannam villai, Kalu heenaty, Sudu heenaty, Pola el, Kalu bala wee, Kahatawalu, Dahanala and Niyan wee* were clustered in one cluster showing high homology. IR64, Gonabaru, Rathl and Ma wee were clustered in different clusters indicating their significant difference from cluster I. First five principle components (PCs) were significant and they accounted for 79 % of total variation. Selected varieties have a significant difference according to clustering pattern. Significant descriptors of PC1 to PC5 can be used to differentiate selected varieties.

Keywords: Morphological characters, Multivariate analysis, Traditional rice

* Corresponding author email: *b. krishanthi@gmail.com* (M.M.K.Bandara)

1. Introduction

Rice continues to be important as a cereal crop which provides more than half of the world dietary energy supply. It is the major staple food for the majority of the people in developing countries where the economy is based on Agriculture. Though the demand for rice has increased during the last decade, production has affected due to reasons like unfavorable weather, decrease of cultivating area and low prices in the market (FAO, 2016). Rice harbor a high genetic diversity and a set of important characters which make it potent to face the challenges brought by unfavorable conditions in the environment. Although it is difficult to gauge the exact rice genotype diversity, it is estimated to be around 140,000 (FAO, 2003). There are more than 40,000 genes mapped in the rice genome. Though the functions of most genes are unknown (IRRI, n. d.).

Out of the south Asian countries, Sri Lanka has a great contribution to the global rice production as it is one of the top twenty rice producing countries per capita (FAO, 2015).

There is a great diversity of the Sri Lankan rice germplasm including improved varieties and traditional varieties which are grown in the fields of lowland and upland. Records in Genbank indicate about 4,000 accessions including wild relatives, land races and old cultivars (FAO, 2007). The majority of the fields are occupied with improved varieties and traditional varieties are grown in a limited area. Due to consumer demand in the recent years, traditional varieties have received an attention as they have beneficial characters such as medicinal and nutritional quality of seeds and environmental stress tolerance capabilities. Information on such characters is needed in genetic improvement programs such as breeding and genetic engineering in order to achieve the target of producing better varieties. Though there are no available scientific evidence about such characters. Therefore, there is a great need of morphological characterization of Sri Lankan traditional rice varieties. This study was aimed to evaluate the variability of selected Sri Lankan traditional rice varieties with respect to vegetative and reproductive characteristics.

2. Materials and Methods

2.1 Selection of Plant Materials

Seeds of twenty four traditional rice varieties and IR64 were selected for the study, based on the knowledge available on their important characters. Seeds of selected varieties (Table 1) were obtained from Plant Genetic Resource center, Gannoruwa, Peradeniya, Sri Lanka.

2.2 Experimental Design and Data Collection

Plants of each variety were grown in pots with surface soil (3.5 kg) which were obtained from a paddy field. Two plants were grown in a pot and five replicates were prepared from each variety. Plants were grown in well watered condition and supplemented with Urea, Triple super phosphate and Murate of potash as recommended by Department of Agriculture, Sri Lanka (Fertilizer usage in paddy cultivation, 2010).

Table 1: Selected Rice Varieties for the Characterization

SN	Rice Accession No	Rice Variety	SN	Rice Accession No	Rice Variety
1	3724	*Goda Heenaty*	14	3762	*Vannam villai*
2	4203	*Thawalu*	15	4705	*Rathal*
3	4024	*Al wee*	16	3200	*Kalu heenaty*
4	4724	*Goda el wee*	17	4126	*Ma Wee*
5	3408	*Pachchaperumal*	18	2088	*Sudu heenaty*
6	4045	*Godamanel*	19	4915	*Pola el*
7	3919	*Godawee*	20	3158	*Kalu bala wee*
8	3263	*Kottiyaran*	21	5476	*Kahatawalu*
9	3242	*Kara el*	22	3540	*Dahanala*
10	2105	*Batapola el*	23	3543	*Gonabaru*
11	3573	*Pokkali*	24	4909	*Niyan wee*
12	3326	*Hetada wee*	25	2280	*IR64*
13	3388	*Moddai karuppan*			

Fifteen morphological and yield characteristics were used for the characterization of plants. They were leaf length, leaf width, length of ligule, length of auricle, culm circumference, number of tillers, number of productive tillers, length of panicle, days for 90 % emergence, number of days for 90 % maturity, spikelet fertility, grain length, grain width, grain thickness and weight of 100 grains. Selected rice accessions were characterized using standard evaluation system (IRRI, 2002) and Descriptors for rice, *Oryza sativa* L (IRRI, 1980). Selected morphological characters were measured using the above mentioned guides and data were analyzed by multivariate analyzing tools.

2.3 Data Analysis

Principal component analysis (PCA) was carried out to assess the variation of the selected morphological characters. Selected rice accessions were grouped based on the variability of the selected morphological characters by performing single linkage cluster analysis. Multivariate analyzing tools provided by IBM SPSS 16.0 statistical software were used for the analysis.

3. Results and Discussions

3.1 Cluster Analysis

Rice varieties were grouped into 5 significant clusters at 15 minimum distance between clusters (Figure 1). Rice varieties were clustered as cluster I comprising twenty one

varieties (*Goda heenati, Thawalu, Al wee, Goda el wee, Pachchaperumal, Godamanel, Goda wee, Kottiyaran, Kara el, Batapola el, Pokkali, Hetada wee, Moddai karuppan, Vannam villai, Kalu heenaty, Sudu heenaty, Pola el, Kalu bala wee, Kahatawalu, Dahanala* and *Niyan wee*) and other four clusters II, III, IV and V comprising single variety each. Clustering of twenty one varieties into one cluster (cluster I) shows the homology of the varieties with respect to measured characters.

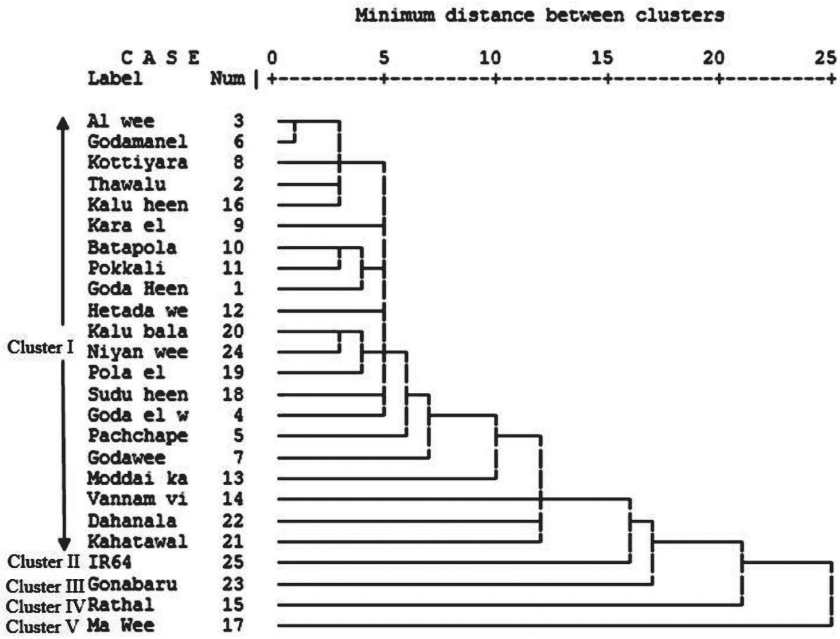

Figure 1 Dendogram Resulted from Single linkage Analysis

Clustering of IR64, *Gonabaru, Rathal* and *Ma wee* in four different clusters indicates their significant difference from cluster I according to the variability of analyzed fifteen characters. According to the results of the study conducted by Suriygoda *et al*. (2011) traditional rice varieties were clustered into two major groups showing higher variation in morphological characters. According to the dendogram most related two varieties were *Al wee* and *Godamanel* as they have shortest minimum distance between them forming the first cluster.

According to the results of PCA, five principle components (PCs) were identified as significant in creating variation having Eigen values greater than one (Figure 2). First five PCs accounts for the 79% of total variation. PC1 accounts for 30% and PC1 and PC2 together account for 51% of variance. Leaf length, leaf width, ligule length, culm circumference,

culm length, panicle length, grain width and grain weight are significant components of PC1 which contributed positively (Table 2). Significant components of PC2 are auricle length, culm length, days for 90% emergence and number of days for maturity.

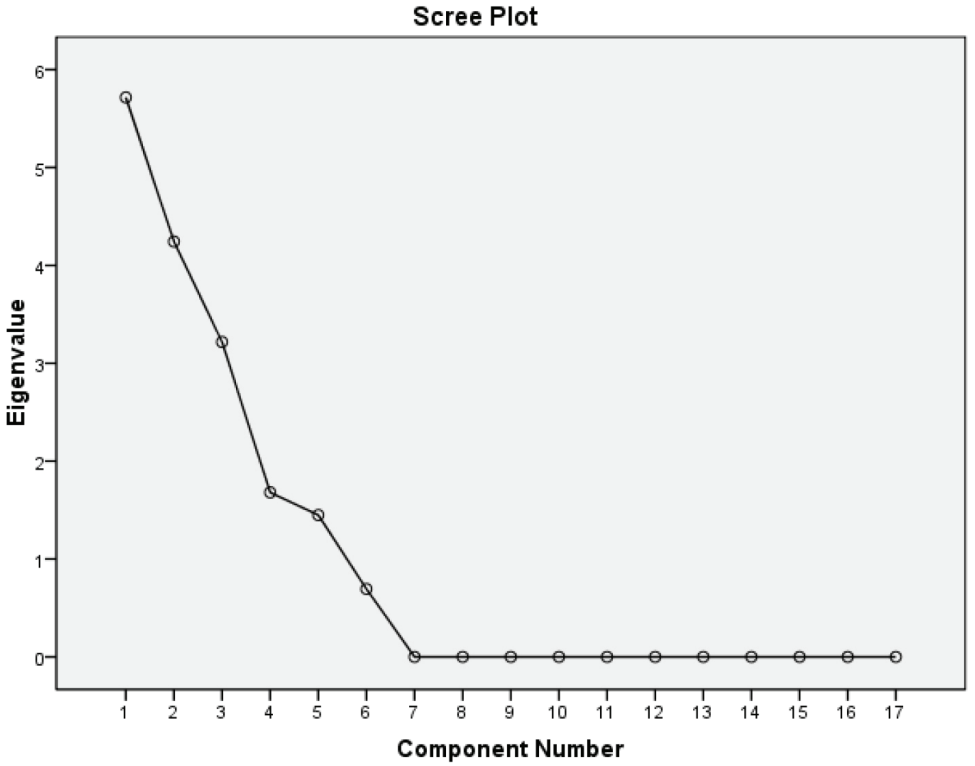

Figure 2: Scree plot showing Principle components Extracted through PCA Components in which Eigen value greater than one are significant

Tehrim *et al.* (2012) reported the helpfulness of agro morphological characters in preliminary characterization of Pakistani rice cultivars which is complementary to this study. Further they stated that first two principle components account for 50 % of total variability which is nearly similar to results of this study. Significant components of PC1 and PC2 of their study are similar to extracted significant components of this study. PC1 shows highest score for *Mawee, Rathal, Gonabaru* and lowest for *Pachchaperumal* (Figure 3). Out grouped traditional varieties from cluster I shows extremely high PC1 scores. PC1 scores for traditional varieties in cluster I are lower than the scores other varieties. PC2 score is highest for *Dahanala* and lowest for *Kahatawalu*, though there is no clear difference of PC2 score among clusters.

Table 2: Component matrix extracted from PCA Components higher than 0.5 have significant contribution to PC

Component	PC1	PC2	PC3	PC4	PC5
Leaf length	0.595	-0.16	-0.124	-0.028	-0.594
Leaf width	0.529	0.039	0.521	0.204	-0.472
Ligule length	0.616	-0.054	-0.161	-0.456	-0.14
Auricle length	0.065	0.669	-0.287	0.218	-0.047
Culm circumference	0.805	-0.121	0.341	-0.012	-0.219
Culm length	0.614	0.54	0.161	-0.184	0.378
Tiller number	-0.68	0.408	0.297	0.318	-0.007
Productive tillers	-0.694	0.337	0.377	0.336	-0.056
Panicle length	0.549	-0.551	0.288	-0.102	0.287
Days for 90% emergence	0.38	0.855	0.059	-0.114	-0.088
Days for 90% maturity	0.331	0.88	0.123	-0.136	-0.106
Spikelet fertility	0.235	-0.513	0.442	0.13	0.296
Grain length	0.358	-0.094	-0.728	0.439	-0.005
Grain width	0.654	0.031	0.168	0.639	0.112
Grain thickness	0.384	0.43	0.006	-0.178	0.5
Grain weight	0.776	-0.005	-0.22	0.455	0.22

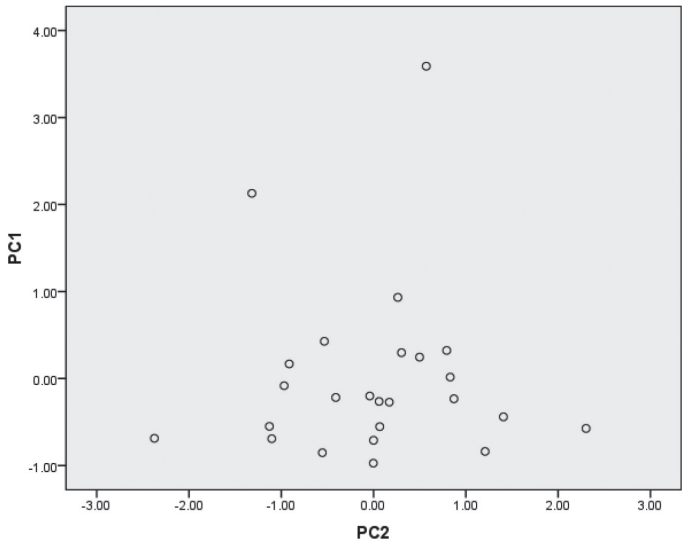

Figure 3: Score plot of PC1 and PC2 based on the results of PCA

According to the results, there is a variability in analyzed characters for selected varieties, though most varieties clustered into one group. Specifically IR64 clustered into a separate group. Therefore, it is clear that the descriptors, used in this study are suitable for studying variability of the selected rice varieties with respect to morphology. Wijayawardhana *et al.* (2015) has confirmed the effective use of agro morphological characters to characterize Sri Lankan rice accessions. Results of single linkage analysis together with PCA provide the evidence for suitability of morphological descriptors used for studying diversity of selected Sri Lankan traditional rice varieties.

4. Conclusions

Selected Sri Lankan traditional rice varieties show a significant variation according to the clustering pattern. Out of descriptors used in this study, significant descriptors of PC1 to PC5 can be used to differentiate the selected Sri Lankan traditional varieties.

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Lateral Branch Induction of Cordyline (*Cordyline fruticosa*) Shoot Cuttings with Benzyl Amino Purine (BAP)

Palugaswewa, P.S.[1], Krishnarajah, S. A.[2], Mahendran, S.[1] and Puvanitha, S.[1*]

[1] Department of Agricultural Biology, Faculty of Agriculture, Eastern University, Sri Lanka
[2]Research and Technology Transfer, Royal Botanic Gardens, Peradeniya, Sri Lanka

Abstract: The Cordyline (*Cordyline fruticosa*) is an important ornamental foliage plant species belongs to Asparagaceae family grown in the tropical and sub-tropical regions of the world. Cordyline has high demand in local and foreign markets as potted and cut foliage plants. Owing to very slow growth rate of cordyline CVs, obtaining leaves with preferred length and quality is difficult. Availability of quality planting material is also a major problem in cordyline cultivation, due to slow growth rate. This study focussed on the possibility of lateral branch induction with Benzyl Amino Purine (BAP) on the decapitated cordyline plants. Cordyline shoots of about 25 cm length were potted in polyethylene bags (6 cm x 15 cm) filled with 1:1 ratio of compost and sand. Shoots were kept for three weeks in the shade before decapitation. Application of different concentrations of BAP as: 25, 50, 75 and 100 ppm were made twice: 1st, three weeks after plant establishment and 2nd, two weeks afterwards as a foliar spray while the control was sprayed with distilled water. The length and the number of lateral branches and also the number of leaves per plant were recorded at fortnight interval starting from two weeks after the last hormone treatment. It was found that the application of BAP at 75 ppm was the most effective in inducing lateral shoots and leaves on cordyline plants. Treatment with 75 ppm BAP has given the highest number of lateral branches; 6−7/tree with 14 −19 leaves compared to the rest of the treatments in both hormonal applications. The length of shoots was also increased markedly due to the application of hormone. The highest length (24.4 and 38.6 cm) was observed in plants treated with 75 ppm BAP. The findings of this study indicated that the application of 75 ppm BAP can be beneficial for lateral shoot induction and growth enhancement of cordyline trees compared to the other treatments.

Keywords: BAP hormone, Cordyline plants, Lateral shoots, Weeks after plant establishment (WAP).

* Corresponding author email : *spuvani@gmail.com* (Puvanitha, S.)

1. Introduction

Floriculture industry is one of the most economically important sectors in Sri Lanka. Foliage crops have taken an important place among the floriculture crops. Cordyline is one of the most impressive foliage plants and it has plenty of varieties. Various colour combinations and shapes of leaves give attraction to cordyline plants. Flowering occurs for eight to ten weeks (Arkins, 2003) and is heavier every second year. Propagation through cordyline hardwood stem cuttings takes three to five years to get decent-sized plants (Harris, 2001). Plant growth regulators and appropriate soil conditions are two of the important factors affecting the growth of plants. Cytokinin and Auxin are the two plant growth regulators that are associated with plant growth (Fishel, 2009). Cytokinin regulates cell division, retention of chlorophyll, promote light induced formation of chlorophyll, lateral bud development, cell expansion and regulation of source/sink relationship (Mazher *et al.*, 2011). Thus, efficient propagation method could be practiced by using 6−Benzyl Amino Purine (BAP) hormone. BAP is a group of cytokinin that influence cell division and shoot formation. Soad *et al.* (2010) have found that BAP has significant effects on growth parameters of *Codiaeum variegatum* plants in terms of plant height, number of branches and leaves per plant, root length and leaf area as well as fresh and dry weights of stems, leaves and roots compared with the untreated plants. According to Tennekoon *et al*. (2010) the use of Benzyl amino purine (BAP) and Indole acetic acid (IAA) has improved the growth performance and quality of *Chlorophytom comosum*, an ornamental foliage. Liemt, 2003 proved that BAP at 150 mgL^{-1} has given the highest value for the number of branches per plant and stem diameter compared with the other treatments (50 and 100 mgL^{-1}) and control plants (0 mgL^{-1}) and this result may be due to the stimulatory effects of BAP (Soad *et al*., 2010). Mazher *et al*. (2011) have revealed that foliar application of kinetin (synthetic cytokinin) has significantly affected the plant height, number of branches, fresh and dry weight of herbs as well as total carbohydrates, protein and total carotenoids in plants such as *Salvia officinalis, Lavandula officinalis* and *Tagetes minuta*. Asadi *et al*. (2009) have reported that Rose 'Morrasia' cultured on Murashige and skoog (MS) medium in vitro showed the highest number of shoots produced in media with 3 mgL^{-1} BAP without NAA. Thus the present study was conducted to determine the application of different concentrations of Benzyl Amino Purine on the number and lengths of lateral shoots and the number of leaves of cordyline plants and to find out the most effective BAP concentration to obtain the highest number and length of lateral shoots and leaves on cordyline plants.

2. Materials and Methods

This experiment was conducted at the Royal Botanic Gardens, Peradeniya from October 2015 to February 2016. Polyethylene bags

of 6 cm diameter and 15 cm height were used for this study, the bag were filled with compost and sand at a ratio of 1:1. A length of 25 cm matured and healthy cordyline plant shoots were potted which were collected from the Royal Botanic gardens, Peradeniya, Sri Lanka. Application of different concentrations of BAP (25, 50, 75 and 100 ppm) was done twice (3 WAP and 5 WAP) as a foliar spray while the control was sprayed with distilled water. Solid form of BAP dust was taken and was weighed amounting to 25, 50, 75 and 100 mg. The weighed hormones were put into 4 beakers and a quantity of 3 mL of diluted HCl was poured to dissolve the hormone. The contents of the beaker were stirred and each solution was volumerized to 1,000 mL to obtain 25, 50, 75 and 100 ppm BAP solutions. Three weeks after planting, all the shoots were detopped including the control. Cuts were made at 18 cm above the soil surface. The cut ends were treated with Captan fungicide ($1gL^{-1}$) to prevent fungal infection. The first application of BAP hormone was sprayed 3 weeks after the plant establishment (3 WAP) and the second application (5 WAP) was done 14 days after the first one. The experiment was laid out in the Completely Randomized Design with five treatments and three replications. Each replication consisted of 8 plants. A total number of 120 bags were used for this study. The treatments were as follows:

T_1 – 25 mgL^{-1} BAP was sprayed – 25 ppm concentration

T_2 – 50 mgL^{-1} BAP was sprayed – 50 ppm concentration

T_3 – 75 mgL^{1} BAP was sprayed – 75 ppm concentration

T_4 – 100 mgL^{-1} BAP was sprayed – 100 ppm concentration

T_5 –Distilled water was used as the control

Two weeks after the first hormonal application, the second application (5 WAP) was done and the data on the number and length of lateral shoots and the number of leaves were recorded. The data were statistically analysed and the difference between treatment means was compared using DMRT.

3. Results and Discussions

3.1 Effects of BAP on the number of shoots

There were significant ($P < 0.05$) differences between treatments on the number of lateral shoots of cordyline plants in both hormonal applications (Figure.1). Subjecting shoots to different concentrations of BAP hormone has significantly ($P< 0.05$) increased the number of lateral shoots compared to the control treatment. Significantly highest mean number of lateral shoots (6 and 7) were observed at 75 ppm BAP treatment after the first (3 WAP) and second application (5 WAP) of BAP hormone while the lowest mean number of lateral shoots (2 and 4) was found at 100 p pm BAP hormone concentration.

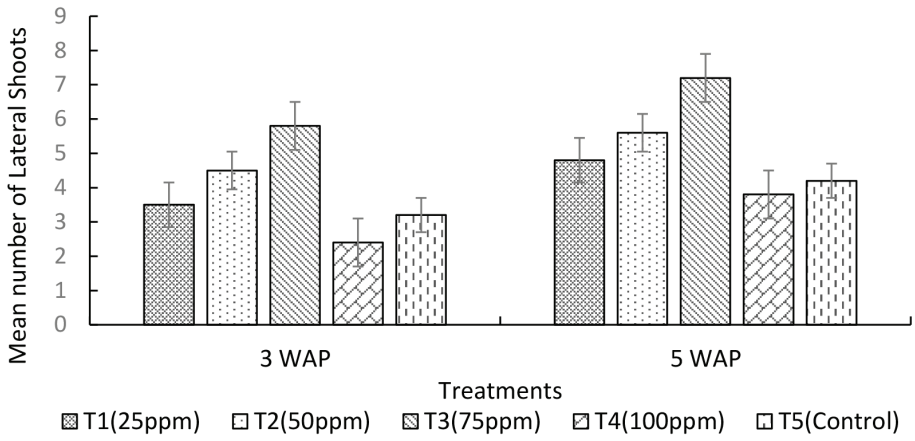

Figure 1: Effects of BAP hormone on the number of lateral shoots of cordyline plants

Mok and Mok (2001) revealed that cytokinin have a major role on plant development, such as the regulation of shoot formation and multiplication and the promotion of cell division and expansion. Benzyl Amino Purine (BAP) is a plant growth regulator which increases branching in floricultural crops when sprayed on containerized plants. Spraying BAP on plants stimulates cell division and increases cell numbers (Schmulling, 2002). Hence, application of BAP has resulted in higher number of lateral shoots. The most effective treatment which has given significantly ($P<0.05$) highest number of lateral shoots was T_3 (75 ppm). Increasing the concentration of BAP increased the number of shoots of plants. Studies of Khaleghi *et al*. (2008) on *Alstroemeria* cv. "Fuego" showed that the greatest number of shoots was obtained from the medium supplemented with 1.5 mgL^{-1} BAP and 0.2 mgL^{-1} NAA. Benedetto *et al*. (2010) found that the application of exogenous cytokinin can improve plant growth at commercial facilities.

There were significant ($P<0.05$) differences between treatments in the length of lateral shoots of cordyline in both hormonal applications (Figure 2). T_3 showed the highest shoot length (24.2 and 38.6 cm) and the lowest length (15.3 cm) observed in T_4 at first hormonal application (3 WAP) and in T_5 (26.4 cm) at second hormonal application (5 WAP). There was a significant ($P< 0.05$) increase in the shoot length of cordyline plants when treated with 75 ppm BAP compared to the rest of the treatments (Figure 2). Based on the biological effects of cytokinin compounds, foliar application of BAP stimulated cell division and increased cell numbers and therefore resulted in increased shoot length of these plants. This increase was in accordance with the results found by Garner *et al*. (1998) which showed that BAP application on tomato plants has increased the shoot length.

3.2 Effects of BAP on the length of lateral shoots

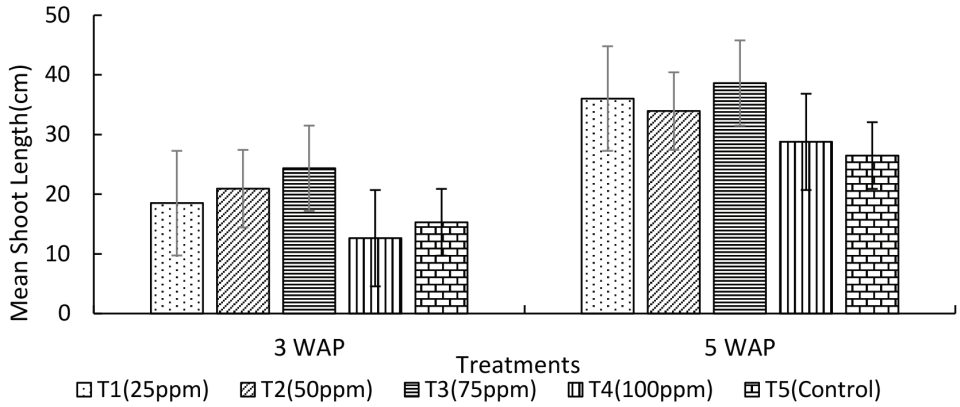

Figure 2: Effects of BAP hormone on the lateral shoot length of cordyline plants

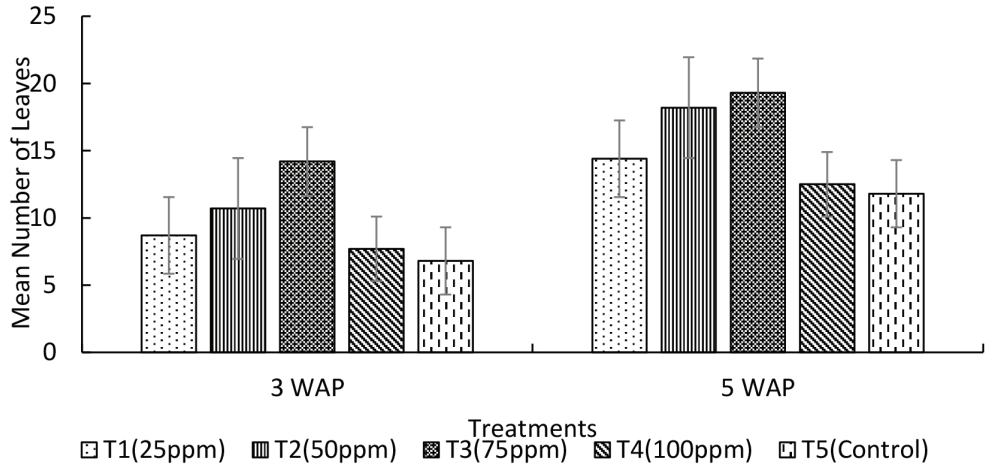

Figure 3: Effects of BAP hormone on the number of leaves of cordyline plants

It was found that there were significant ($P<0.05$) differences between treatments in the number of leaves of cordyline plants at both hormonal applications (Figure 3). Number of leaves on cordyline plants is an important aspect with regard to export market. More number of leaves per plant is the most important in cordyline production. The highest number of leaves (14 and 19) was observed in T_3 (75 ppm) and the lowest number (6 and 11) was found in T_4 (100 ppm) treatment. Tennekoon *et al*. (2010) when did experiments with *Chlorophytum comosom* found that the number of leaves per sucker and number of suckers have increased significantly in 75 mgL^{-1} IAA

in combination with 75 mgL^{-1} BAP in 1:1. While BAP encourages cell division and cell expansion. The success of cell division, elongation and expansion may have led to increase in the length of leaves. Schmulling (2002) stated that increasing the number of leaves is the role of BAP through cell divisions and assimilated transport. Foliar application of BAP stimulated cell division and increased cell numbers and therefore resulted in increased number of leaves. This increase was in accordance with that found by Haratian and Mortazaeinezhad (2015).

4. Conclusions

This study was conducted to increase the production of cordyline plants by hormonal application. Increase in the number of lateral shoots produced from single cutting is the major factor in the propagation of cordyline plants. The highest number and length of shoots were obtained from plants treated with 75 ppm BAP hormone. Hence, 75 ppm BAP hormone was identified as the most effective strength of the hormone to produce highest number and length of cordyline shoots and highest number of leaves on cordyline plants. The results of this study could be useful to commercialize cordyline plant production.

Acknowledgment

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Effect of Thermal Treatment on Keeping Quality of Palmyrah Sweet Sap

Surenther, S.[1], Mahilrajan, S.[2]*, Chandrasena, G.[1], Robika, K.[2] and SriVijeindran, S[2]

[1]Uva Wellassa University, Badulla, Sri Lanka
[2]Palmyrah Research Institute, Kandy Road, Jaffna, Sri Lanka

Abstract: The palmyrah palm (*Borassus flabellifer*) is grows extensively in Northern part of Sri Lanka. Sweet sap is the most important product obtained from palm, could be extracted from both male and female inflorescences (dioecious) by tapping process. Harvested sap should be immediately processed due to the highly perishability as it under goes spontaneous fermentation via air born yeast microflora. The main objective is the study was to identify the optimum temperature and time for preservation of sweet sap and detected the suitable shelf life for bottled sweet sap via the physical, chemical, microbiological and sensory quality of preserved sweet sap. Traditionally quick lime is added to prevent the fermentation; phosphoric acid was selected at pH 8 based on the sensory analysis for the removal of lime as calcium phosphate. Delimed sweet sap was used for the study of thermal treatment in order to increase the keeping quality of sweet sap. Three experiments with different thermal treatments were conducted to preserve the sweet sap. Experiment 1 (preservatives such as citric acid and sodium metabisulphite) and as a result of gas formation due to the fermentation, Experiment 2 (thermal treatments of 60, 70 80 and 90 ^{o}C) were rejected. In the 3rd experiment the bottled sweet sap was heated at 105, 110 and 115 ^{o}C for different time intervals (15 and 30 min) and stored at room temperature (30±2 ^{o}C). There were no significant differences ($p<0.05$) in physicochemical (TSS, total and reducing sugar) and microbial (TPC and yeast and mould) evaluation of selected treatments at 60 days of storage. Based on sensory evaluation, thermal processing at 105 ^{o}C for 15 min was selected as the best treatment and it could be stored for 60 days without changing its native characteristics.

Keywords: Palmyrah, Preservation, Sweet sap, Temperature and Time

1. Introduction

The palmyrah palm (*Borassus flabellifer* L.) is present in tropical part of Sri Lanka, East Asia and Africa. The most important product of palmyrah palm is the sap. It could be extracted from the male or female

* Corresponding author email *: jsubajini@gmail.com* (Mrs. Subajini Mahilrajan)

inflorescences during January to August by the process known as "tapping (Theivendirarajah, 2008). Palmyrah inflorescence unfermented sap called as sweet toddy (neera or pathaneer), contained medicinal properties (Vengaiah *et al.*, 2013) and yielding a healthy nutritious drink. It is the one of the most important products, because it is rich in sugars, minerals (Kapilan *et al.*, 2015), if it is left exposed to the atmosphere; it undergoes both enzymatic and microbial fermentation within a couple of hours and become alcoholic beverage called as toddy (Davis and Johnson, 1987). Spontaneous fermentation of sap is caused by accumulation and growth of yeast from the air (Jeyaratnam *et al.*, 1984), at present arbitrary quantities of lime (calcium hydroxide) is used to arrest fermentation (Mary *et al.*, 2014). This is unsuitable for ready to serve drinks or for the preparation of natural treacle, sugar candy and jaggery as value added products. Consequently it needs further de-limeing steps for the production of value added products. However, the sap is seasonal and can be obtained only in the first and second quarter of a year, therefore the production of sap based products cannot be done throughout the year and also no approved preservation methods are available to preserve palmyrah sweet sap. This study was carried out with the aim to conserve the fresh sweet sap with increased the shelf life using suitable thermal preservation method. Therefore the main objective is this study was to identify the optimum temperature and time for the preservation of sweet sap and to detect the suitable shelf life period for storage of bottled sweet sap.

2. Materials and Methods

2.1 Sample Collection

Pooled palmyrah sweet sap was obtained from the Chavakachcheri palm development society and used for the preservation study.

2.2 Analysis of Fresh Sweet Sap

Collected sweet sap was filtered with muslin cloth and the initial parameters (pH and alcohol content) were measured to ensure the quality of sap.

2.3 Selection of De-limeing Agent

Food grade acids such as citric acid, maleic acid, phosphoric acid and tartaric acid were used to determine the suitable agent for neutralization of sap (de-limeing) and increase settling of sediments, A 5 points Hedonic scale test in terms of colour, flavour, appearance, mouth feel and overall acceptability was carried out for selection of best de liming agent of palmyrah sweet sap.

2.4 Selection of Suitable pH for De-limeing

Diluted (1:4) phosphoric acid (food grade) was added until the pH was brought for 7, 8, 9, 10 and 11. Then direct heat was applied to 60 ^{o}C, for the above pH adjusted sap separately and allowed to settle for 1 hour. Most suitable pH was selected through the sensory panel. A 5 points Hedonic scale test was carried out to the selection of optimum pH.

2.5 Preservation Techniques

Three experimental trials with different treatments were conducted during this study.

Experiment trial I: The pH of the de-limed sap was adjusted at 4.5 with citric acid then used for the treatments I and II (contained SMS - 50 ppm). Treatment III (pH = 8) was not contained no additives and used as a control. All the treatments were bottled then heated at 90 ^{o}C for 20 min and allowed to cool at room temperature. Then heat treated bottled sweet sap were used for sensory evaluation immediately.

Experiment trial II: The de-limed bottled sweet sap without any additives was heated at 60, 70, 80 and 90 ^{o}C for different time intervals (10, 20 and 30 min) and allowed to cool at room temperature. Then heat treated bottled sweet saps were stored at room temperature and were used for sensory evaluation at 24 h of storage.

Experiment trial III: The de-limed bottled sweet sap without preservative was heated at 105, 110 and 115 ^{o}C for different time intervals (15 and 30min) then allowed to cool at room temperature. Then heat treated bottled sweet saps were stored at room temperature and were analyzed at 30 day intervals to determine the shelf life of bottled sweet sap.

2.6 Sensory Analysis

The sensory evaluation (5 point hedonic scale test) was conducted by 30 untrained sensory panelists were selected from palmyrah research staff. The best treatment was selected in terms of colour, flavour, appearance, mouth feel and overall acceptability through statistical analysis.

2.7. Physiochemical Analysis

pH (Sension+ pH 31-Spain pH meter), total sugar (Miller, 1959), reducing sugar (Miller, 1959), alcohol (ebulliometerDujardin-Salleron), acidity (Sri Lanka Standard Institute, 1985) and brix value were evaluated in 30 days intervals.

2.8 Microbial Analysis

TPC (Sri Lanka Standard Institute, 1985) and yeast and mould count Sri Lanka (Standard Institute, 1992) were determined in monthly intervals.

2.9 Statistical Analysis

The sensory data with duplicate were analyzed using non-parametric procedure, according to the Friedman test using Minitab 16 software package.

3. Results and Discussions

3.1 Analysis of Fresh Sweet Sap

Fresh sweet sap was oyster white colour sap due to the addition of lime to arrest the fermentation. pH of the collected sap was 11.0, this results was agreed with Velauthamurty *et al.,* 2015 and there were no alcohol content.

3.2 De-limeing of Sweet Sap

Selection of de-limeing agent: Lime is

added to sap to prevent the fermentation (Mohanadas, 1974) due to the application of lime the pH of the sweet sap was more than 10. Therefore de-liming was carried out with different acids such as citric acid, malic acid, phosphoric acid, tartaric acid to reduce the pH of the sweet sap and form insoluble lime salts. Colloidal matters such as pectins, hemicelluloses, proteins and colored compounds are absorbed by the precipitated ions (Nair *et al.*, 2009). During the de-liming process sweet sap was heated at 60 °C to increase the precipitation of calcium phosphate and some colloids flocculation. Based on the median values of the sensory attributes, phosphoric acid (Figure 1) was selected as best acid among the selected acids. During this process, a wide range of chemical and physical reactions takes place in the sap. The main chemical reactions include precipitation of calcium phosphate, denaturation of proteins (and other organics, such as gums, pectins and waxes), inversion of sucrose due to the combined action of pH and temperature, degradation of reducing sugars to organic acids due to high pH and temperature, precipitation of organic and inorganic acid salts and formation of colour groups due to the polymerisation (either enzymatically or thermally) of phenolic compounds.

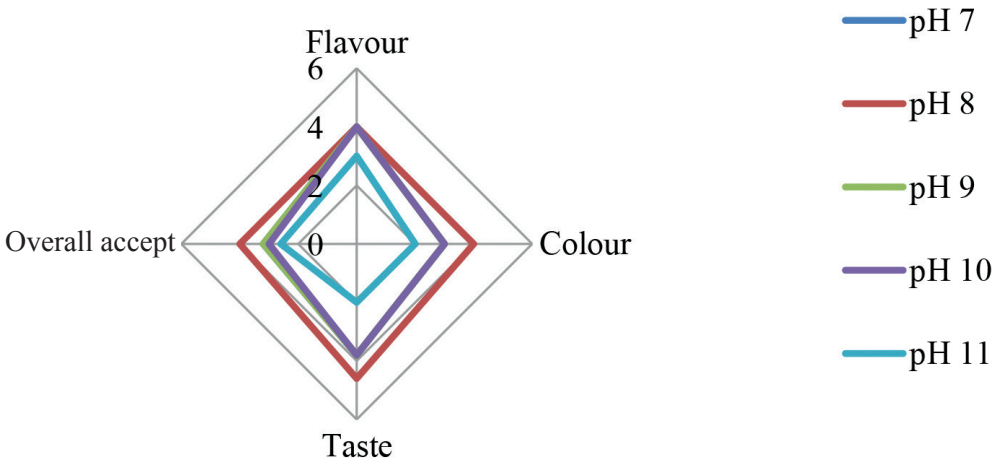

Figure 1: Web diagram for selection of de-limeing agent

Selection of pH for de-limeing: The initial pH of the sweet sap was more than 10 therefore it was de-limed to the appropriate pH such 7, 8, 9 and 10 and the best pH was selected based on the sensory attributes. There were no significance differences in median values of the flavour between different pH while colour, taste and overall acceptability were showed highest median values for pH 8. Calcium phosphate is more soluble at low temperatures, when the sap is heated there are competing reactions between the unreacted

calcium and phosphate, the formed calcium phosphate and sap constituents. Formation of calcium phosphate is spontaneous and complete at pH 7.8 with the heating process. Therefore, pH 8 was selected as the best de-limeing pH. Further, it had shown the highest value for quality attributes according to the web diagram (Figure 2). Australian cane sugar industry is best described as simple defecation of unwanted substance, is based on the addition of lime as lime saccharate to intermediate juice (72–76 °C) at pH of 7.8 (King, 1930).

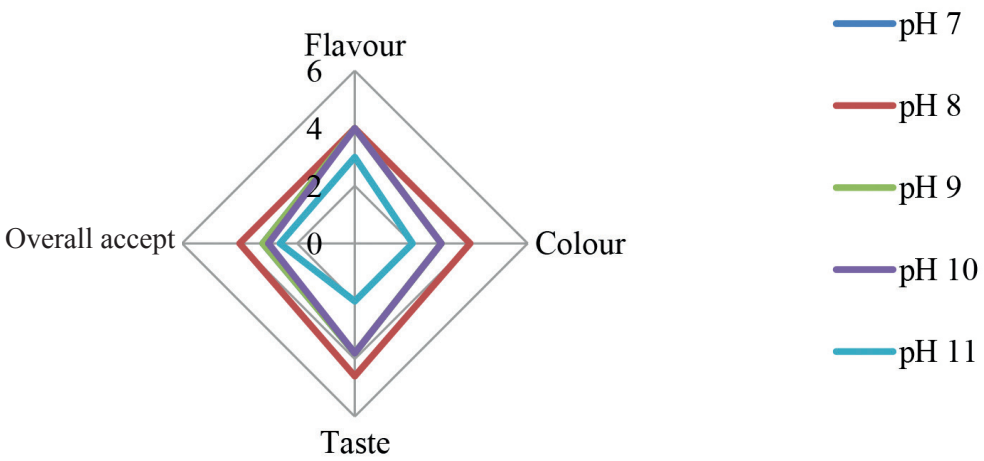

Figure 2: Web diagram for selection of pH

Heat treatments for bottled sweet sap: Sweet sap is highly susceptible to natural fermentation at ambient temperature within a few hours of collection from the palm. Once fermented, it transforms into toddy with 4 % alcohol. Using several technologies developed by various research institutes, sweet sap is processed and preserved in its natural form to retain the vitamins, sugar, and other nutrients beneficial for health. Heat preservation methods such as pasteurization and sterilization are necessary to preserve and extend the shelf life of the product.

Experiment I: Mohanadas (1974) preserved coconut sap at acidic pH, therefore this experiment was designed at acidic pH 4.5 (Treatment I), with preservative (Treatment II) and without preservative at pH 8 (Treatment III). Based on the sensory evaluation treatment I and II were rejected. While treatment III was selected as the best treatment at the 24 hours of storage.

Experiment II: Thermal treatments 60, 70, 80 and 90 °C were applied for 10, 20 and 30 min and stored at room temperature. All the above treatments were spoiled at 48 h of storage and gas formation was observed. Mohanadas (1974) reported that coconut sap could be preserved by the heat treatments: 80 °C for 25 min and 90 °C for 20 min using Lanka Glass Co. bottles. However, it was not recommended storage temperature.

According to the results of our experiments, it was found that sweet sap by heat treating 80°C for 30 min, could be stored for six months at 4°C.

Experiment III: Nair *et al*. (2013) reported that thermal processing of coconut neera at a temperature of more than 95 °C and reduction of thermal stress by addition of bio-preservative 'nisin' at a concentration of 10 ppm was found to enhance shelf life of coconut neera. Therefore, in this experiment different temperature, such as 95, 100, 105, 110, and 115 °C for different time intervals (15 min, 30 min) without preservatives were selected (T1−T10). Microbial analyses of thermal treated sweet saps were done at initial period of storage. Treatment (T1) (95 °C, 15min) , T2 (95 °C, 30 min), T3 (100 °C,15 min) and T4 (100 °C, 30 min) contained TPC and yeast and mould count which were more than microbiological tolerance limit (Sri Lanka Standard Institute, 1985). Therefore treatment 1, 2, 3 and 4 were rejected and the rest of the treatments (T5−T10) were analyzed at 30 days' time intervals (Table 1). Median value of colour (higher color intensity) and taste was less for treatments T8 and T10 due to the increasing rate of melanoidin formation through the Maillard reaction specifically monosaccharides present in the sap react with amino acids under the alkaline condition.

Table 1: Estimated median value obtained from sensory evaluation of selected treatments at initial time of storage

Quality attribute	T5 105°C, 15 min	T6 105°C, 30 min	T7 110°C, 15 min	T8 110°C, 30 min	T9 115°C, 15 min	T10 115°C, 30 min	P value
Flavour	4.000	4.000	4.000	4.000	4.000	3.000	0.00
Colour	5.000	4.833	4.083	3.917	4.000	3.167	0.00
Taste	4.896	3.979	4.062	3.895	4.062	3.479	0.00
Overall acceptability	4.938	4.271	4.021	3.937	4.021	3.021	0.00

3.3 Sensory Evaluation of Selected treatments

According Table 1 treatment 5 (Temperature 105 °C, Time 15 min) showed the highest estimated median value for quality attributes such as colour, taste, flavour and overall acceptability at initial time of storage. While there were no significant different in median value of quality attributes between the storage periods (Table 2). Therefore, treatment 5 was selected as the best treatment for bottling of sweet sap.

Table 2: Estimated median value obtained from sensory evaluation of best treatment (T5) at different storage period

Quality attributes	0 time	30 days	60 days
Flavour	4.000	4.750	4.750
Colour	5.000	4.917	5.000
Taste	4.896	4.708	5.000
Overall acceptability	4.938	4.958	5.000

3.4 Physicochemical Analysis

Reducing sugar: The reducing sugar content (Table 3) of bottled sweet sap treated with different treatments under different temperature and time period showed significant different between storage period. In the case of reducing sugar analysis 0.16 % was taken as a hypothetical mean (Theivendirarajah, 2008). According to the (t-test) result the p-value is 0.00, it is less than the tested value at 5 % significance level. So this statistical result strongly proved that whole value is greater than hypothetical mean value

Table 3: Amount of reducing sugar for selected treatments (g/100mL)

Temperature (°C)	Time (min.)	Treatments	0 time	30 days	60 days
105	15	5	0.165±(0.012)	0.183±(0.014)	0.173±(0.011)
	30	6	0.159±(0.014)	0.185±(0.012)	0.186±(0.013)
110	15	7	0.164±(0.013)	0.190±(0.015)	0.178±(0.017)
	30	8	0.164±(0.011)	0.186±(0.015)	0.184±(0.014)
115	15	9	0.172±(0.012)	0.193±(0.013)	0.179±(0.012)
	30	10	0.157±(0.015)	0.186±(0.014)	0.216±(0.016)

Total sugar: According the Table 4 at 0 times of storage all treatments having more than 11 % of total sugar content. The fresh sap total sugar limit was 10-16 %. At 30 and 60 days of storage amount of total sugar was decreased with increasing the temperature and also decreased with increasing the storage period while the rate of decreasing amount of total sugar was less in 105 °C for 15 min than other treatments. Therefore 105 °C for 15 min is more suitable for the sweet toddy preservation.

Brix value: Brix is the measurement in percentage by weight of total soluble solids in sweet sap. According to the Table 5 the t-test result showed that the p-value as 0.00 and it seems that this value is lower than tested ($p<0.05$) significance level. Samples having the Brix value 11 was taken as a hypothetical mean (Jeyaratnam, 1986). These statistical results strongly proved that whole values were greater than the hypothetical mean value therefore all values are suitable for sweet toddy.

Table 4: Amount of total sugar for selected treatments (g/100 mL)

Temperature (°C)	Time (min.)	Treatments	0 time	30 days	60 days
105	15	5	12.664±(0.012)	9.639±(0.011)	8.427±(0.013)
	30	6	11.234±(0.015)	9.264±(0.014)	8.375±(0.016)
110	15	7	11.644±(0.018)	9.264±(0.015)	7.965±(0.016)
	30	8	11.600±(0.015)	8.942±(0.014)	7.364±(0.018)
115	15	9	11.165±(0.015)	7.460±(0.015)	7.434±(0.018)
	30	10	11.016±(0.014)	7.268±(0.011)	7.381±(0.013)

Table 5: Brix value (TSS) for selected treatments

Temperature (°C)	Time (min.)	Treatments	0 time	30 days	60 days
105	15	5	11.12	11.19	11.24
	30	6	11.11	11.12	11.23
110	15	7	11.05	11.08	11.13
	30	8	11.04	11.06	11.12
115	15	9	11.02	11.12	11.14
	30	10	11.00	11.06	11.12

TPC and Yeast count for the treated sweet toddy: The number of colony count (cfu/ml) in NA and PDA plates at 0 to 60 days of storage was less than that of limit (less than 50) present in the Sri Lanka Standard (Sri Lanka Standard Institute, 1985)

Alcohol and acidity content: Sugars present in sweet toddy undergo first alcoholic fermentation and then acidic fermentation consequently on the action of microorganism (Theivedirarajah, 1986) . There were no alcohol and acid formation in the all treatments. The total sugar content was decreased and reducing sugar was increased with storage however conversion of the sugars to alcohol via glucose metabolism was not observed. Therefore it was due to conversion of total sugar to reducing sugar and physic chemical changes in the sap with storage.

4. Conclusions

During the sweet sap collection spontaneous fermentation is take palace, which is prevented by the application of quick lime on the colleting pots. Phosphoric acid was found to be the best de-limeing agent based on the sensory, microbial and physic chemical characteristics. Preservation of sweet sap by heating at 105°C for 15 min was selected as

the best treatment and this heat treated sap was stored for 60 days at room temperature without changing its native characteristics.

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Evaluation of Seed Biopriming and Organic Manures on Chilli Organic Seed Production

Ananthi, M.*, Selvaraju, P. and Sundaralingam, K.

Seed centre, Tamil Nadu Agricultural University, Coimbatore – 03

Abstract: To find out the effect of seed bio-priming with liquid bio-fertilizers and application of sources of nutrients on crop growth and yield of Chilli, a field experiment was conducted at the Department of Seed Science and Technology, Tamil Nadu Agricultural University, Coimbatore on 2013 during *Kharif* and *Rabi* seasons. The results revealed that the plant growth and yield parameters were more in the plants grown from bio-primed seeds with *Azospirillum* than the non-primed seed. Among the sources of nutrients, the performance of inorganic fertilizer was higher than organic manures. Among the organic manures, seed bioprimed with *Azospirillum* and applied with poultry manure recorded the plant height of 66.2 and 63.9 cm, leaf area index of 1.665 and 1.621 and chlorophyll index of 44.9 and 43.9 in both the seasons. The same results were obtained with respect to number of flowers plant^{-1}, number of fruits plant^{-1} and fruit set percentage which were significantly higher in *Azospirillum* biopriming seed with inorganic fertilizer than organic treatments. The seed yield was high in the treatment involving seed bio-priming with *Azospirillum* and inorganic fertilizer (219.1 and 212.6 kgha^{-1}) followed by poultry manure (213.5 and 207.4 kgha^{-1}) than in the control (209.5 and 205.0 kgha^{-1}) in both the seasons.

Keywords: Chilli seed, Liquid biofertilizers, Organic manures

1. Introduction

The cultivable land resource is shrinking day by day with the increase in population. To meet the food, fibre, fuel, fodder and other needs of the growing population, the productivity of agricultural land and soil health needs to be improved. Therefore, for sustaining the productivity of the crop, maintaining the soil health and healthy ecosystem, there is a need for adoption of an alternative system is organic farming. Organically grown products are expected to fetch higher price and this can offset any loss due to lower yield (Motsara, 2000). There is a greater demand in the international market for organically produced chilli. Since it is used almost daily in our food preparations as a spice. Chilli is a low-volume, high-

* Corresponding author email *: ananthiagri87@gmail.com* (M. Ananthi)

value seed. Since the seed costs are high, it is important for growers to obtain healthy, plantable seedlings from every seed sown. Delayed or erratic seedling emergences are serious problems that result in the production of non-uniform seedlings of low vigour in the nursery (Demir and Okeu, 2004). Faster emergences are essential pre-requisites for high quality seedling production, especially among transplanted vegetables. Sustainable crop production requires the adoption of eco-friendly seed enhancement techniques. One such treatment is seed bio-priming. Bio-priming is a seed pre-treatment that integrates the biological and physiological aspects of enhancing growth, improving disease control, and increasing yields.

A challenging task in organic seed production is the supply of balanced nutrition through organic manures. Unbalanced supply of nutrition may lead to nutrient deficiency and physiological disorders leading to poor growth and development, ultimately reduction of productivity. Technologies have been developed to produce large quantities of nutrient rich manure. It is understood that organic manures are rich in carbon fractions and their addition to the soil act as a source of energy for microbial population that encourages proliferation of soil microorganism, increased microbial populations and activity of microbial enzymes i.e., dehydrogenase, urease and nitrogenase (Bakry *et al.*,2009). Chilli crop responds well to the application of both organic manures and inorganic fertilizers. Organic manures in farming had advantages like nutrient conservation, slow releases and improvement in soil physical conditions and help in efficient nutrient management in a cropping system. Keeping the above research gaps in view, investigations were made by conducting field studies with chilli cv. PKM 1 with the objective of the effect of seed bio-priming with liquid bio-fertilizers and application of sources of nutrients on seed yield and quality.

2. Materials and Methods

Genetically pure, fresh seeds of chilli (PKM 1) obtained from the Department of Seed science and Technology, Tamil Nadu Agricultural University, Coimbatore formed the base material for this study. The liquid bio-fertilizers viz., Azospirillum and Phosphobacteria collected from the Department of Agricultural Microbiology, TNAU, Coimbatore-3 and farm yard manure, poultry manure and vermicompost obtained from the Department of Farm management and Animal Husbandry, TNAU, Coimbatore-3 also formed the materials for this study. In this experiment, chilli seeds bio-primed with liquid bio-fertilizers (*Azospirillum* 10 percent for 9h and phosphobacteria 15 percent for 9 h) and the non-primed (control) seeds were sown in protray and were transplanted in the main field 35 days after sowing. Field experiments were conducted by adopting split plot design with two replications in two seasons namely (*Kharif* 2013) and (*Rabi* 2013). The main plot treatments were

bio-primed seed (*Azospirillum* 10 per cent for 9 h and phosphobacteria 15 per cent for 9 h) and non-primed seed (Ananthi *et al*., 2014). There were seven sub plot treatments namely (i) recommended doses of NPK @ 60:30:30 kgha^{-1} (ii) 100 % RDF through farm yard manure (iii) 100 % RDF through poultry manure (iv) 100 % RDF through vermicompost (V) 50 % FYM + 50 % PM (vi) 50 % FYM + 50 % VC and (vii) 50 % PM + 50 % VC. The observations on growth and yield parameters were recorded from each treatment in replication wise.

2.1 Growth Parameters

Five plants were selected randomly from each treatment, replication wise for measuring the following observations.

Plant Height (cm): Height of the plant was measured from the ground level to the tip of the growing plant in five plants in each plot at 90 days after transplanting and mean value was expressed in centimetre.

Leaf Area Index: Leaf area was measured in randomly selected five plants at 90 days after transplanting and calculated using the following formula;

$$LAI = \frac{Leaf\ area\ per\ plant}{Ground\ area\ occupied\ by\ the\ plant}$$

Chlorophyll Index (SPAD values): Chlorophyll content was observed in randomly selected five plants at 90 days after transplanting at morning. Chlorophyll meter from Minolta (Model SPAD 502 of Co., Japan) was used to measure SPAD values (Anon., 1989). The third uppermost fully expanded leaf was measured and the mean value was worked out. SPAD meter (Konica, Minolta) was used to measure the chlorophyll content of the leaf. It quantifies green colour in plants immediately by non-destructive measuring method (Yadav, 1986). The chlorophyll meter calculated the SPAD value based on the intensities of light transmitted in the red band (around 650 nm) where absorption by chlorophyll is high and in the infrared band (around 940 nm) where absorption is low.

3.2 Yield and Yield Components

Number of Flowers: The total number of flowers from randomly selected five plants were counted and the mean values were expressed as number of flowers plant.

Number of Fruits: The number of fruits harvested in randomly selected five plants was recorded and the mean value expressed as number of fruits plant.

Fruit set Percentage: The fruit set percentage (FSP) was calculated by counting the number of flowers converted into fruits in randomly selected five plants in each plot as follows:

$$FSP = \frac{Number\ of\ fruits\ per\ plant}{Number\ of\ flowers\ per\ plant}$$

Fruit weight: The fruits harvested in each picking, treatment wise and replication wise in the randomly selected five plants were weighed and mean was expressed in gram.

Seed Yield: The well ripened fruits collected from each picking from the randomly selected plants were dried, and kept in paper bag. Seeds were extracted by beating the fruits with pliable sticks. Then, the seeds were sieved using BSS 8 × 8 sieve, and the seeds retained on the sieve were weighed and expressed in gram. Seeds extracted from the fruits harvested from each plot, treatment wise were dried and weighed. The seed yield was expressed in gram. Seed yield was calculated from the plot yield and expressed in $kgha^{-1}$

3.3 Statistical Analysis

The data obtained from various experiments were analysed statistically adopting the procedure described by Panse and Sukhatme (1985). Wherever necessary, the percent values were transformed to angular (arcsine) values before analysis. The critical differences (CD) were calculated at 5 percent probability level. The data were tested for statistical significance. If the F test is non-significant, it was indicated by the letters NS.

4. Results and Discussions

4.1 Growth Parameters

Statistically significant differences were observed for the growth parameters with bio-priming treatments. Among the main plot treatments, seeds bio-primed with 10 per cent *Azospirillum* for 9 h recorded maximum plant height (64.2 and 62.0 cm), leaf area index (1.611 and 1.499) and chlorophyll index (43.4 and 42.6) at 90 days after transplanting than non-primed seeds in both the seasons. Among the sub plot treatments, plant height (66.2 and 64.9 cm), leaf area index (1.659 and 1.665) and chlorophyll index (45.7 and 44.5) were also more in the plants grown from the bio-primed seed with *Azospirillum* and applied with recommended dose of fertilizer when compared to non-primed seed with respect to plant height (64.8 and 64.0 cm), leaf area index (1.639 and 1.642) and chlorophyll index (42.8 and 40.9). Among the organic manures, seed bio-primed with *Azospirillum* and basal application with poultry manure recorded the plant height of 66.2 and 63.9 cm, leaf area index of 1.665 and 1.621 and chlorophyll index of 44.9 and 43.9 outperforming others in both the seasons (Table 1 and 2).

Significant increase in plant height may be attributed to more nitrogen fixation by *Azospirillum* isolates that can be used by the plant (Rodrigues *et al.*, 2008) and production of phyto-hormones like indole-3-acetic acid, indole-3-butyric acid, gibberellic acid and cytokinin (Fallik *et al.*, 1988; Bottini *et al.,* 1989). Improvement in growth parameters due to *Azospirillum* treatment to the seeds recorded in this study is in agreement with results of Kanimoli *et al.* (2004), Santa *et al.* (2004), El-Kholy *et al*. (2005), Gomathy *et al.* (2007), Puenette *et al*. (2009) and Yadav *et al.* (2011b) in maize and Diaz – Zortia and Fernandez – Canigia (2009) and Yadav *et al.* (2011a) in wheat.

Table 1: Effect of seed biopriming and source of organic nutrients on plant height (cm), leaf area index and chlorophyll index at 90 DAT in chilli cv. PKM 1 in *Kharif* 2013

Main plot / Subplot treatments	Plant height (cm)				Leaf area index				Chlorophyll index			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
RDF (Inorganic) (S_1)	64.8	67.8	66.1	66.2	1.64	1.68	1.66	1.66	42.8	45.7	44.3	44.3
100% farmyard manure (S_2)	58.5	60.0	59.2	59.2	1.51	1.51	1.49	1.50	39.5	41.0	40.2	40.2
100% poultry manure (S_3)	63.1	66.2	64.9	64.7	1.62	1.67	1.64	1.64	41.6	44.9	44.0	43.5
100% vermicompost (S_4)	62.7	65.5	64.0	64.1	1.61	1.66	1.64	1.64	41.5	44.1	43.2	42.9
50% FYM+50% PM (S_5)	60.3	63.1	61.6	61.7	1.55	1.58	1.55	1.56	40.9	42.6	41.5	41.7
50% FYM+50% VC (S_6)	59.2	61.9	60.7	60.6	1.53	1.53	1.53	1.53	40.3	41.8	40.9	41.0
50% PM+50% VC (S_7)	62.0	64.9	63.2	63.4	1.57	1.65	1.58	1.60	41.1	43.7	42.9	42.6
Mean	61.5	64.2	62.8		1.58	1.61	1.58		41.1	43.4	42.4	
	M	T	M×T	T×M	M	T	M×T	T×M	M	T	M×T	T×M
SEd	0.25	0.46	0.78	0.80	0.002	0.002	0.004	0.003	0.091	0.100	0.185	0.174
CD (P=0.05)	0.50	0.92	1.56	1.60	0.005	0.004	0.007	0.006	0.184	0.205	0.372	0.350

RDF- Recommended dose of fertilizer- 60:60:30 kg NPK ha^{-1}, M_1- Nonprimed seeds; M_2 - Biopriming with *Azospirillum* 10 % for 9h; M_3 - Biopriming with Phosphobacteria 15 % for 9 h , ; DAT-Days after transplanting, SEd- Standard error of deviation, CD-Critical difference

Table 2: Effect of seed biopriming and source of organic nutrients on plant height (cm), leaf area index and chlorophyll index at 90 DAT in chilli cv. PKM 1 in *Rabi* 2013

Main plot / Subplot treatments	Plant height (cm)				Leaf area index				Chlorophyll index			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
RDF (Inorganic) (S_1)	64.0	65.7	64.9	64.9	1.642	1.695	1.659	1.665	40.9	44.5	43.2	42.9
100% farmyard manure (S_2)	57.0	58.2	57.9	57.7	1.251	1.306	1.282	1.280	37.2	40.9	39.6	39.2

100% poultry manure (S_3)	61.9	63.9	63.1	63.3	1.540	1.621	1.585	1.582	40.1	43.9	42.7	42.2
100% vermicom-post (S_4)	61.0	63.2	62.3	62.2	1.515	1.560	1.527	1.534	39.3	40.3	41.9	41.4
50% FYM+50% PM (S_5)	59.6	61.0	60.1	60.2	1.427	1.421	1.406	1.418	38.1	42.1	40.6	40.3
50% FYM+50% VC (S_6)	57.0	59.7	58.5	58.4	1.389	1.397	1.325	1.370	37.7	41.4	40.1	39.7
50% PM +50% VC (S_7)	61.2	61.5	60.9	61.2	1.472	1.495	1.472	1.480	38.7	42.7	41.0	40.8
Mean	60.2	62.0	61.1		1.462	1.499	1.465		38.8	42.6	41.3	
	M	T	M×T	T×M	M	T	M×T	T×M	M	T	M×T	T×M
SEd	0.181	0.293	0.503	0.507	0.0035	0.0018	0.0046	0.0032	0.128	0.321	0.531	0.556
CD (P=0.05)	0.368	0.589	1.010	1.016	0.0070	0.0039	0.0092	0.0065	0.259	0.645	1.065	1.115

RDF- Recommended dose of fertilizer- 60:60:30 kg NPK ha^{-1}, M_1- Nonprimed seeds; M_2 – Biopriming with *Azospirillum* 10 % for 9 h; M_3 – Biopriming with Phosphobacteria 15 % for 9 h, DAT–Days after transplanting, SEd–Standard error of deviation, CD–Critical difference

Inorganic fertilizers recorded maximum growth parameters because inorganic fertilizers might have promoted the N uptake essential for efficient photosynthesis and faster growth rate resulting in increased plant height. This is in conformity with the earlier findings of Raja (2003), Sundaralingam (2005) and Vijayan (2005) in hybrid rice. The promotive effect of nitrogen and phosphorous on plant height may be due to the better synthesis of amino acids which help in cell multiplication and elongation.Inorganic fertilizers might have improved photosynthetic activity resulted in increased synthesis and translocation of photosynthates in the plants and subsequently higher dry matter content of the plant (Wange and Kale, 2004).

In organic seed production, application of poultry manure to the bioprimed seed could able to contribute added advantage in increasing the growth parameters.The positive effect of organic manure on plant height could be due to the contribution made by manure to the fertility status of the soils as the soils were low in organic carbon content. Increased plant height as a result of poultry manure was due to the presence of high phosphorus content which increased the availability of native soil phosphorus and increased biological activity (Adilakshmi *et al,* 2008). The results are in conformity with the results of Yadav *et al.*, (2004) and Karthika (2013) in okra. Poultry manure was

readily available and in the best form for easy absorption by the plant roots, hence there was a boost in the morphological growth of the plant.

3.2 Yield Parameters

In the present study, fruit set percentage (82.6 and 81.5) and seed yield (219.1 and 212.6 kg ha^{-1}) was more due to seeds bio-primed with Azospirillum grown under inorganic fertilizer. Among the organic manures, seed bio-primed with *Azospirillum* and applied with poultry manure recorded the fruit set percentage of 81.0 and 79.6 and seed yield of 213.5 and 207.4 kg ha^{-1} outperforming others in both the seasons (Table 3 and 4).

Table 3 : Effect of seed biopriming and source of organic nutrients on fruit set percentage (%) and seed yield $plant^{-1}$ (g) and seed yield ha^{-1} (kg) in organic seed production in chilli cv. PKM 1 in *Kharif* 2013

Main plot / Subplot treatments	Fruit set percentage (%)				Seed yield / plant (g)				Seed yield / ha (kg)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
RDF (Inorganic) (S_1)	80.2	82.6	81.0	81.3	8.50	8.97	8.78	8.75	209.5	219.1	215.5	214.7
100% farmyard manure (S_2)	69.3	72.9	69.6	70.6	7.52	7.79	7.65	7.65	164.2	174.5	172.4	170.4
100% poultry manure (S_3)	79.0	81.0	79.6	79.9	8.33	8.50	8.42	8.42	210.1	213.5	211.0	211.5
100% vermicompost (S_4)	76.3	79.4	77.1	77.6	8.05	8.29	8.15	8.16	201.5	205.5	203.0	203.3
50% FYM+50% PM (S_5)	72.2	75.9	73.9	73.9	7.84	8.00	7.96	7.93	183.5	195.3	188.2	189.0
50% FYM+50%VC (S_6)	70.5	74.4	71.0	71.7	7.75	7.94	7.90	7.86	176.0	187.2	179.5	180.9
50% PM+50%VC (S_7)	74.8	78.0	75.3	76.0	7.95	8.14	8.06	8.05	194.5	200.1	197.0	197.2
Mean	74.6	77.6	75.4		7.99	8.23	8.13		191.3	199.3	195.2	
	M	T	M×T	T×M	M	T	M×T	T×M	M	T	M×T	T×M
SEd	0.102	0.402	0.352	0.396	0.019	0.031	0.053	0.054	0.071	0.257	0.418	0.445
CD (P=0.05)	0.205	0.805	0.704	0.792	0.041	0.065	0.108	0.113	0.145	0.519	0.841	0.892

RDF- Recommended dose of fertilizer- 60:60:30 kg NPK ha^{-1}, M_1- Nonprimed seeds; M_2 - Biopriming with *Azospirillum* 10 % for 9 h; M_3 - Biopriming with Phosphobacteria 15 % for 9 h SEd- Standard error of deviation, CD- Critical difference

Table 4 : Effect of seed biopriming and source of organic nutrients on fruit set percentage (%) and seed yield plant $^{-1}$ (g) and seed yield ha^{-1} (kg) in organic seed production in chilli cv. PKM 1 in *Rabi* 2013

Main plot / Subplot treatments	Fruit set percentage (%)				Seed yield / plant (g)				Seed yield / ha (kg)			
	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean	M_1	M_2	M_3	Mean
RDF (Inorganic) (S_1)	79.4	81.5	80.7	80.5	8.40	8.92	8.68	8.67	205.0	212.6	210.9	209.5
100% farmyard manure (S_2)	69.4	72.1	71.9	71.1	7.49	7.70	7.62	7.60	166.1	171.8	168.9	168.9
100% poultry manure (S_3)	76.5	79.6	78.9	78.3	8.15	8.32	8.28	8.25	204.0	207.4	205.0	205.5
100% vermicom post (S_4)	74.8	78.4	77.5	76.9	8.01	8.25	8.19	8.15	198.0	200.9	199.0	199.3
50% FYM+50% PM (S_5)	71.1	75.5	74.8	73.9	7.81	7.99	7.95	7.92	183.9	191.8	187.4	187.7
50% FYM+50% VC (S_6)	70.6	73.6	73.2	72.7	7.77	7.92	7.89	7.86	174.9	179.8	177.3	177.3
50% PM+50% VC (S_7)	73.7	76.7	75.5	75.3	7.93	8.10	8.05	8.03	191.8	197.0	193.9	194.2
Mean	73.6	76.9	76.1		7.94	8.17	8.09		189.1	194.5	191.8	
	M	T	M×T	T×M	M	T	M×T	T×M	M	T	M×T	T×M
SEd	0.187	0.188	0.355	0.325	0.004	0.012	0.020	0.021	0.203	0.421	0.706	0.730
CD (P=0.05)	0.380	0.379	0.711	0.652	0.010	0.026	0.045	0.045	0.410	0.849	1.419	1.465

RDF– Recommended dose of fertilizer- 60:60:30 kg NPK ha^{-1}, M_1– Nonprimed seeds; M_2 – Biopriming with *Azospirillum* 10 % for 9 h; M_3 – Biopriming with Phosphobacteria 15 % for 9 h , SEd- Standard error of deviation, CD– Critical difference

The possible reason for increase in number of fruits per plant in Azospirillum may be attributed to the production of various endogenous hormonal levels in the plant tissues that may enhance the pollen germination and tube growth which ultimately, may increase the fruit set per plant (Balasubramanian, 1988). The fruit set percentage were increased due to the production of more number of branches per plant (Gosavi *et al.*, 2011) due

to the immediate availability of nutrients to the plants from inorganic source.

The increase in seed yield observed in the present study due to growth substances produced by *Azospirillum* might have accelerated the carbohydrate accumulation and increased metabolic activities leading to heavy seed weight and higher seed yield (Singh *et al.*, 2003). It was observed that *Azospirillum* inoculation significantly increased the yield of several crops upto 30 % (Sumner, 1990; Okon and Labandera Gonzalez, 1994; DallaSanta *et al.*, 2004). The best performance in terms of seed yield with the application of inorganic fertilizer might be due to the availability of optimum dose of nutrients to plant to complete and maintain its physiology (Kunzanglamo *et al.*, 2012). Similar results were also reported by Malik *et al*. (1988) in mung bean and Srinivas and Shaik (2002) in greengram. However, inorganic plot received P and K at a dose of 60 and 30 kg ha^{-1}, respectively, whereas organics might not supply the required quantity of P and K to the plants and that could be one of the reasons for the superiority of inorganic plots.

4. Conclusions

It is concluded that, seed bio-priming with *Azospirillum* 10 per cent for 9h along with 100 per cent RDF through poultry manure was the best treatment for organic manure nutrition.

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Ecosystem Services of Homegarden Agroforestry in Jaffna Peninsula

Jeyavanan, K.[1]*, Sivachandiran, S.[1] and Pushpakumara, D.K.N.G.[2]

[1]Department of Agronomy, Faculty of Agriculture, University of Jaffna, Sri Lanka
[2]Department of Crop Science, Faculty of Agriculture, University of Peradeniya, Sri Lanka

Abstract: A study was carried out in Jaffna peninsula in dry zone area of Sri Lanka to assess the ecosystem services of homegarden agroforestry. Participant observation, interview of householders, measuring and collection of biodiversity data, photographing and sketching the structure of homegardens and focus group discussion were approached. In samples of 125 homegardens, a total of 5,920 individuals for flora were assessed from 58 families and 135 species. Mean value of Shannon diversity index (H), Simpson diversity index (D) and evenness (E) for the floristic component were 1.72 ± 0.04 (0.2-2.95), 0.78 ± 0.12 (0.27-1) and 0.81 ± 0.01 (0.12-1.19), respectively, revealed that the homegardens had medium, equally distributed floral diversity in Jaffna homegardens. A total of 825 individuals for domestic fauna were identified from 19 species and 12 families, H, D and E were 0.21 ± 0.03, 0.16 ± 0.03 and 0.22 ± 0.03, respectively, revealed that faunal component had low species diversity and not equally distributed among the homegardens. Mean above ground carbon stock was 40.51 ± 3.67 (235.71-0.33) Mg C ha^{-1}. Provision of fruits was high with mean of 2,996 kg ha^{-1} and nuts from coconut was 1, 444 nuts ha^{-1}. Mean production of milk from goat and cattle were 0.44 and 1.09 litre day^{-1} $animal^{-1}$, respectively. Mean volume of producible trees and poles were high accounted as 36.68 and 2.12 m^3 ha^{-1} $homegarden^{-1}$, due to high species density. Annual mean production of fodder for livestock was 875.99 ± 395.4 kg ha^{-1}, revealed that about 3.68 % of feed requirement could be met for livestock. There were more than 30 medicinal plants including trees, shrubs and vines used in ethno medicine. Mean value of income, expenditure and food ratio was Rs. 21,976, Rs. 18,802 and 0.56, respectively. Host per pollinator and pollinators per host were high in bees and mango, respectively. Effectiveness of the temperature and shade was medium-cool and medium-high, respectively in inside the homegardens, revealed that tree canopy play a key role to regulate the environment. Effectiveness of different conservation practices on soil, water, nutrient and biodiversity was medium, low-medium, medium and low, respectively.

Keywords: Agroforestry, Ecosystem Services, Homegarden, Jaffna Penisnsula

* Corresponding author email *: kjvanan@gmail.com* (K. Jeyavanan)

1. Introductıon

Homegarden agroforestry system is the well planned and systematically managed cycles as a specialized way of farming and growing of high valued cultural trees, crops and animals together in appropriate manner and oldest and integral land use activity, next to shifting cultivation. It is suggested that all homegarden systems have evolved to provide food and other requirements of households and accounts 13.1 % of the total land area of the country (Pushpakumara *et al.,* 2012). Ecosystem services refer to the final benefits that are enjoyed or consumed by beneficiaries, including agroecosystems that are useful to humans or support human well-being (Gómez-Baggethun and De Groot, 2010). Ecosystem services are basically categorized into provisioning of goods, regulating services, cultural services and supporting services and plays a key role in production, protection, financial benefits and livelihood development to society (MA, 2005) Assessment of ecosystem services is the emerging option of agroforestry systems in scientific world. Attempts have been made to identify the ecosystem services of those four categories by several scientists (Mohri, 2013). However, ecosystem services of Sri Lankan agroforestry or any agriculture systems have not been properly identified/ analyzed. Development of homegarden is one of the way to rebuild the environmental, economic, social and food and nutritional secure community by providing the ecosystems services (Marambe *et al.*, 2014). But until recently the up scaling or improvement of homegarden agroforestry systems remains poor throughout the northern and eastern provinces due to prevailed war. As in other areas of the country, homegarden agroforestry has received little attention from policy makers and research institutes (Pushpakumara *et al.*, 2012). Jaffna peninsula is dominated by small holder agriculture and categorized as low country dry zone (DL_3 and DL_4). The total number of farm families in this peninsula is nearly 50 % of the total population which is accounted as 614,541 people (DSH, 2015). Total land available for cultivation is about 12,000 ha out of 102,500 ha. The total forest extent in this peninsula is around 2, 244 ha accounts 2.22 % of total land area in the district and 0.03 % of total land area of Sri Lanka. This result indicates the importance of agriculture and its land use practices and their contribution to ecosystem services of Jaffna peninsula. Thus, the objective of this study was to assess the ecosystem services of homegarden agroforestry in Jaffna peninsula.

2. Methods and Materials

The study was carried out in Jaffna district of the Northern Province of Sri Lanka. Jaffna is located between 09 °40′ N 80 °10′ E. Jaffna district consists of DL_3 and DL_4 agro-ecological regions (Punyawardena *et al.*, 2010). A total of 125 homegardens were assessed for ecosystems services out of identified homegardens during the period from 2014 to 2016. Questionnaire survey includes interview of householders, observation,

measuring and collection of biodiversity data, photographing of homegardens and sketching the structure of homegardens and focused group discussions. The number of species per sample was measured by the term of richness. Evenness was measured by relative abundance of the different species. Species diversity was measured by diversity indices such as Simpson's Diversity index and Shannon-Wiener Index (SWI). Tree height and diameter (DBH) of >= 5 cm) were measured using standard instruments clinometer and diameter tape, respectively. All sample homegardens n =125 were categorized into size of homegardens, namely small (<0.2 ha), medium (0.2-0.8 ha) and large (>0.8 ha). For the biomass, carbon stock and volume calculation, pan tropical allometric equations were used. Biomass of individual trees, banana and palm trees were used in different allometric equation developed by chave *et al.*, 2005 for dry forest, brown (1997) respectively (Table 1). Species specific wood density was followed by wood density database of world agroforestry center. Tree volume of the species were calculated by generic allometeric equation ($Vtree=0.4D^2H$, Where; Vtree = bio-volume of a tree in m^3, D = diameter in meter, H = height in meter, 0.4 is average form factor) followed by Pandya *et al.*, (2013).

Table 1: Generic allometric equation used to estimate the above ground biomass for individual trees, banana and palm in the dry zone homegardens of Jaffna District

Type of above ground biomass	Allometric equation	R^2	Source
Individual trees	$Y=\exp(-2.187+0.916\times\ln(D^2HS))$	0.99	Chave *et al.,* 2005
Banana	$Y=0.030D^{2.13}$	0.99	Hairiah *et al.,* 2010
Palms	$Y=\exp(-2.134+2.530\times\ln(D))$	0.97	Brown, 1997

Y = above-ground biomass density (kg $tree^{-1}$), D = diameter in cm, H = height in m, S = species-specific wood density in g cm^{-3}.

Qualitative data (gender, cultural services) and quantitative (height, dbh and yield) were statistically analyzed. The diversity, richness and evenness of species were computed using the Shannon Weiner and Simpson indices. Different tests were performed for non-parametric variables. Kruskal Wallis test was performed among the group such as small, medium and large sized homegardens. Spearman's Rho non parametric correlation was performed among the variables to find out the relationship. R-studio was used to develop the correlation plot among the variables. Goodness-of-Fit Test was performed to find

out significance of each practices followed by number of homegardeners. Wilcoxon signed rank test was performed to find out the significance within one variables. Analysis of variance (ANOVA) and LSD (p = 0.05) were conducted for parametric variables .Statistical Analysis Software of SAS, 1999 and Minitab 17 were used to analyze the data.

3. Results and Discussions

3.1 Provision services of Homegardens Agroforestry

A total of 5920 flora species were assessed from 58 families and 135 species. In 125 sampled homegardens, fruit crops had high frequency of occurrence followed by palm trees, vegetable crops and filed crops. Figure 1 (a) shows the floristic component in a homegarden. Mean value of Shannon diversity index and Simpson Diversity index were 1.72 ± 0.04 and 0.78±0.12, respectively. Mean value of evenness was 0.81±0.01, shows that the homegardens had medium diversity and species were more or less equally distributed in the Jaffna homegardens. Mean number of species per homegardens was high in small sized homegardens than medium and large sized homegardens. Kruskal-Wallis test shows that Shannon diversity index (H), Simpson diversity index (D) and evenness (E) were statistically significant in relation to size of the homegardens. ($P<0.004$, $P<0.013$ and $P<0.01$, respectively). Medium and large sized homegardens had high H, D and E than all category. Small size homegardens was statistically lower H, D and E. species richness and trees numbers were not statistically differed with size category (Table 2).

Table 2: Value of tree diversity indices in small, medium, large and all categories of Jaffna homegardens

HGs category extent wise	Shannon-diversity Index	Simpson diversity index	Evenness	Species richness	Mean number of tree species
Small *(<0.2 ha, n=100)*	1.65±0.05b 2.96-0.20	0.77±0.01b 1-0.33	0.76±0.02b 1.19-0.12	9.68±0.40a 26-2	48.34±5.72a 479-3
Medium *(0.2-0.8 ha, n=18*	1.89±0.13ab 2.64-0.56	0.80±0.04ab 0.93-0.27	0.80±0.03ab 0.96-0.40	11.11±1.05a 23-4	48.39±8.14a 149-7
Large *(>0.8 ha, n=7)*	2.13±0.07a 2.56-1.51	0.88±0.02a 0.95-0.79	0.88±0.03a 0.98-0.80	11.43±0.65a 13-9	30.71±4.81a 54-15
All categories	1.72±0.04 2.95-0.20	0.78±0.12 1-0.27	0.81±0.01 1.19-0.12	10.74±0.36 26-2	42.48±4.73 479-3

Note: Mean values shows with ± standard error (SE); significant test at $\alpha = 0.05$

(a) (b)

Figure 1: (a) Floristic component in a homgarden, b) a faunal component in a homgarden

A total of 825 domestic fauna were identified from 19 species and 12 family. About 72 homegardens have been growing faunal composition out of 125 homegardeners account 53.33 %. Chicken was the dominant species account 62.59 % (n=472) followed by goat and cattle (Figure 1.b). Galhena. (2012) reported that among the 167 gardens surveyed, 112 gardens contained some combination of livestock including cattle, goats, poultry, or swine, with 79 gardens having cattle, 74 with goats and 85 with chickens. Similarly for domestic fauna, Mean value of Shannon diversity index and Simpson diversity index for fauna were 0.21±0.03 and 0.16 ±0.03, respectively. These result shows that faunal diversity was low in Jaffna homegardens. Mean value of evenness and species richness of the homegardens for fauna were 0.22 ±0.03 and 1.05 ±0.13, respectively, shows that faunal species were not equally distributed among the homegardens (Table 3).

Table 3: Value of faunal diversity indices in small, medium, large and all categories in Jaffna homegardens

HGs category extent wise	Shannon-diversity Index	Simpson diversity index	Evenness	Species richness	Mean number of fauna species
Small *(<0.2 ha, n=100)*	0.19±0.03a 1.35-0.00	0.3±0.03b 1-0.00	0.22±0.04a 1-0.00	0.93±0.11a 4-0	5.73±1.21a 85-0
Medium *(0.2-0.8 ha, n=18)*	0.28±0.12a 1.56-0.00	0.3±0.07b 1-0.00	0.21±0.08a 0.87-0.00	1.39±0.41a 6-0	6.17±2.44a 40-0
Large *(>0.8 ha, n=7)*	0.31±0.16a 1.04-0.00	0.8±0.07a 0.61-0.00	0.33±0.16a 1-0.00	1.86±0.55a 5-1	10.00±3.90a 32-0
All categories	0.21±0.03 1.56-0.20	0.3±0.1 1-0.00	0.22±0.03 1-0.00	1.05±0.13 6-0	6.03±1.05 85-0

Note: Mean values shows with ± standard error (SE), Maximum-Minimum; Significant test at $\alpha = 0.05$.

Fruits was highly contribute to production of foods with mean total of 2995.92 kg ha^{-1} $homegarden^{-1}$. Coconut was dominant palm crops and widespread among the homegardens bring mean of 1, 444 nuts ha^{-1} $homegarden^{-1}$ followed by palmyrah with mean fruits of 832. Homegardens scattered in the country also constitute the most significant production system for fruits in Sri Lanka (Weerakkody, 2004). Galhena., 2012 reported that on an average, 140 kg of vegetables, 408 kg of fruits, and 118 coconuts were produced in homegardens. Average milk production of goat and cattle were 0.44 and 1.09 liter $animal^{-1}$ day^{-1}. Local chicken was dominant in egg production. About 88 % of chicken were in egg producing stage and mean egg production was 35 eggs hen^{-1} $week^{-1}$. Homegardens can capable to produce a mean of 35.68 ± 3.52 m^3 of tree volume ha^{-1} and 4.10 ± 0.40 m^3 of tree volumes $homegarden^{-1}$ (0.21 ha). FSMP (1995) revealed that homegardens produce about 0.95 m^3 of saw logs $year^{-1}$. There were 7 species have been contributing to pole production in JHGs, commonly found in the living fence of the homegardens. Mean pole production was 2.12 $m^3year^{-1}ha^{-1}$. According to FSMP (1995), homegardens produce 0.5 m^3 of $polesha^{-1}year^{-1}$, on average, revealed that pole production was somewhat high in Jaffna peninsula, due to its high population of living fence species. Mean fodder production of grass and trees were 4.82±2.72 and 953.39±273.33 $kgha^{-1}year^{-1}$, respectively. Average fresh fodder requirements of the cattle and goat in sample areas was 2,125.76 $kgyear^{-1}HGs^{-1}$. however, average production of fodder from both grasses and trees was 78.27 $kgyear^{-1}HGs^{-1}$, revealed that HGs was only satisfied 3.68 % of fodder requirements for rearing animals. There were more than 30 medicinally important species including trees (14), shrubs (12), herbs and vines (6), flowering plants (2) were identified in sampled areas. Mean total income of the homegardens per unit area per year was Rs.1, 34, 704.24 (> 1 million rupees in LKR). Fruit crops was contributed to high income of Rs. 107, 027.18 than palm and vegetable crops. Galhena. (2012) also reported that fruit was major income generator in the peninsula. It was generated from sales of milk and eggs as well as sales of individual's livestock (goat) and poultry (finches). Average income from the egg $homegarden^{-1}$ $week^{-1}$ was Rs. 52.09 ±1.91. This was higher than the average income of milk

3.2 Regulating Services of Homegardens Agroforestry

Mean carbon stock is given in Mg C ha^{-1}. Mean carbon stock of all homgerdens in sampled area was 40.51±3.67 ranges from 235.71-0.33 Mg C ha^{-1}. Mean above ground carbon stock was significantly higher ($p<0.05$) in small homegardens (45.47±4.12, n=100, <0.2 ha) followed by medium (27.27±8.76, n=18, n=0.2-0.8 ha) and large (3.68±1.56, n=7, <0.2 ha) sized homegardens (Table2). Small sized homegardens had significantly highest above ground carbon stock followed by medium and large sized homegardens shows that size of the homegardens was negatively correlated with above ground carbon (Table 4). Mattsson *et al.* (2015) reported that mean aboveground biomass

Table 4: Aboveground biomass and carbon stock in small, medium, large and all categories of Jaffna homegardens

HGs category extent wise	Aboveground biomass (AGB, Mg ha^{-1})	Aboveground Carbon (AGC, Mg ha^{-1})
Small *(<0.2 ha), n=100)*	90.93±8.28a (471.41-0.67)	45.47±4.14a (235.71-0.33)
Medium *(0.2-0.8 ha, n=18*	54.55±17.52b (291.58-2.35)	27.27±8.76b (145.79-1.17)
Large *(>0.8 ha, n=7)*	7.36±3.10c (24.00-1.27)	3.68±1.55c (12.00-0.63)
All categories	81.01±7.33 (471.41-0.67)	40.51±3.67 (235.71-0.33)

Note: Mean values shows with ± standard error (SE); significant test at $\alpha = 0.05$

stock of 13 Mg C ha^{-1} with a large ranges from 1–56 Mg C ha^{-1}, n = 45 due to a variation of tree diversity and composition between individual homegardens.

Kruskal-Wallis test result that AGC was statistically significant with size category of the homegardens ($p<0.0001$). Small size homegardens had high AGC from the average AGC for all categories than the medium and large sized homegardens. In sampled homgardens, small and medium sized homegardens had high number of species followed by large sized homegardens. Mean and total number of tree species was high in small sized homegardens followed by medium and large homegardens (Figure 2). Host range or host/pollinator was high in bees and butterflies (16 plants) followed by wasp and birds, revealed that foraging range was high and had an ability to search the food any time (Table 5). Kruskal-Wallis test shows that median practices of prevalence of fully organic practices was above the average rank (62 %) followed by mechanical (41 %) and indigenous or traditional knowledge (40 %), respectively at p value 0.000 (α=0.05) in Jaffna homegardens. Calvet-Mirr, (2012) reported that about 75 % of the studied homegardens received manure or organic products as main fertilizers and organic or manual management methods as main practices to control weeds and pests.

Inside of the homegardens, shade was higher level and temperature was lower level than outside of the homegardens, shows that, reduction of the temperature and increased shade level were mainly due to the tree species in the homegardens. Mean range of temperature were ranges from medium to cool and medium to hot in inside and outside of the homegardens, respectively, similarly, mean range of shade was ranges from medium to high and low to medium in inside and outside of the homegardens, shows that homegardens regulate the temperature and shade lead to reduction of temperature and increased the shade compared to outside of the homegardens (Table 6). Kruskal Wallis test shows that conservation practices conserve the soil and nutrient at medium level than water and biodiversity, revealed that homegardens regulates and enhanced the soil, nutrient, water and biodiversity by several conservation practices (Table 7).

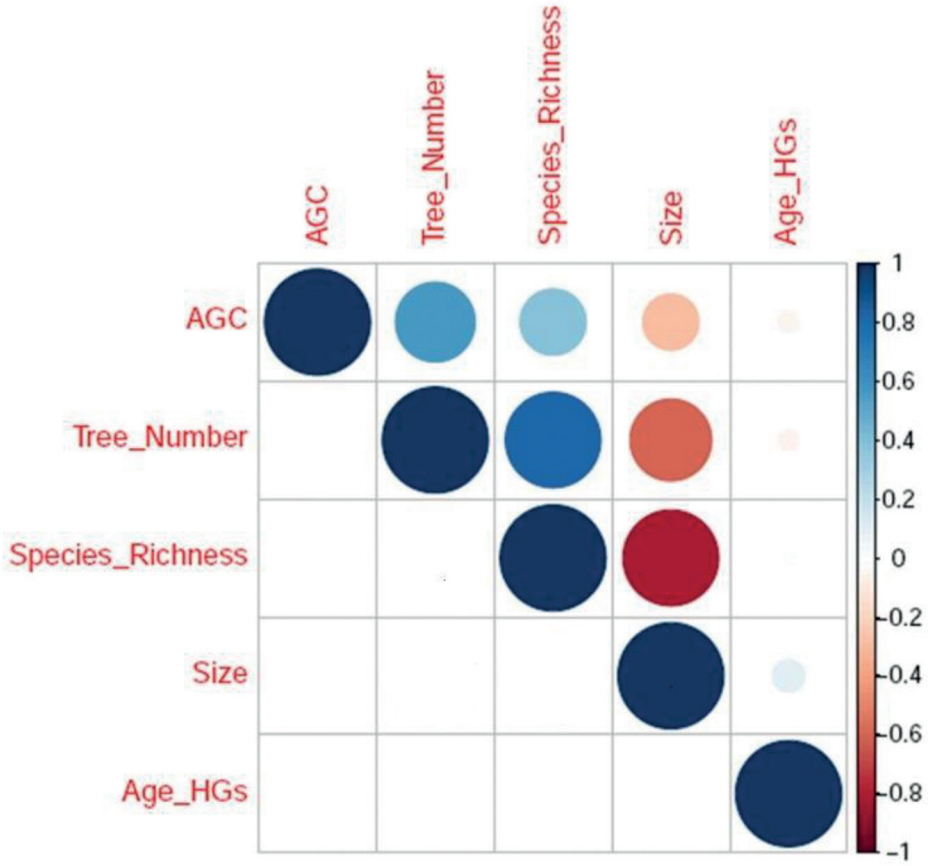

Figure 2: Correlation plot for the variables of age of the homegardens (years), size of the homegardens (ha), species richness (ha^{-1}), number of trees (ha^{-1}) and above ground carbon stock, AGC (Mg C ha^{-1}) in sampled homegardens (n=125); Note: Increasing trend of blue colour shows the increasing of positive correlation among the variables, similarly, brown colour shows the negative correlation of the variables.

Pushpakumara *et al.* (2012) reported that cover crops and mulching are rarely practiced to control soil erosion but a dense cover of dead litter is found on the floor of most homegardens providing the same function.

3.4 Cultural and Supporting Services

Some trees were not preferred within the homegardens with some religious belief of the people such as *Polyalthia longifolia* (Sonn.) Thw. and *Tamarindus indica* L. due to this, these are rarely found in the homegardens. Banana, coconut, arecanut and mango frequently used in all the religious events. *Erythrina variegata* L. (*Erythrina indica* Lam) and *E. subumbrans* (Hassk.) Merr were used in religious event and wedding. Kruskal Wallis test shows that grouping of lifestyle

Table 5: Pollinator-Plant in the homegardens

Host vs. pollinator	Bees	Butterfly	Wasp	Birds	Beetles	Bat	White ants	Moth	Flies	Pollinators/ host
Mango	√	√	√	√	√	√	√	√	√	9
Banana	√	√	√	√	√					5
Bitter gourd	√	√	√		√				√	5
Moringa	√	√	√	√						5
Jampu	√			√		√	√			4
String bean	√	√	√	√						4
Papaya	√	√		√	√					4
Citrus		√	√	√				√		4
Coconut			√	√	√					3
Shoe flower	√	√	√							3
Rose	√	√	√							3
Snake gourd	√	√	√							3
Brinjal	√	√	√							3
Pomegranate	√	√			√					3
Guava				√		√	√			3
Passion fruit		√				√				2
Pumpkin	√				√					2
Tomato	√	√								2
Ponnuchchi	√	√								2
Ixora		√					√			1
Neem	√									1
Hosts/pollinator	16	16	11	9	7	4	4	2	2	

Table 6: Spearman's Rho correlation for temperature and shade levels in inside and outside of the homegardens

Spearman's Rho	Temperature inside of the HGs	Temperature Outside of the HGs	Shade inside of the HGs
Temperature Outside of the HGs	1.00		
Shade inside of the HGs	-0.834**	-0.834**	
	p=0.001	P=0.001	
Shade Outside of the HGs	-0.834**	-0.834**	0.833**
	p=0.001	p=0.001	p=0.001

Result of Spearman rho correlation analysis and, **significant Mann Whitney test result at 0.05.

Table 7: Effectiveness of conservation practice on soil, water, nutrient and biodiversity in JHGs

Conservation methods	Soil	Water	Nutrient	Biodiversity
Hedgerow	Medium	Medium-high	High	High
Mulching	Medium	Low-medium	Medium	Medium-high
Strip cropping	Low-medium	Medium	Medium-high	Medium
Cover crops	Medium	Low	Medium	Medium
Drainage channel	--	Medium	Medium	Low
Ditches	Medium	Low	Medium	--
Organic fertilizer	Medium	High	High	Low
Bund	Medium	Low-medium	Medium	Low
Burning	Medium	--	Medium	--
Heap method	Medium	Low	Medium	Medium
Sprinkler	--	Medium	Low	--
Worm compost	--	--	Medium-high	--
Overall	Medium	Low-medium	Medium	Low
Number of HGs	76	43	29	27

and aesthetic based on the importance were rated significantly as somewhat important and very important for aesthetic and life style (p=0.001). People obtained the aesthetic and ornamental services by mind relax and fresh environment. Kruskal-Wallis Test, reveals grouping of each services shows that mean rank was high for lifestyle followed by aesthetic, health, pleasure and satisfaction among the services (Figure 3). Calvet-Mirr *et al.*, (2012) reported that home gardens provide a large set of ecosystem services, being cultural services the category most valued in the homegardens of Northeastern Spain. Dominant habitat for the seasonal fauna was trees (55 %) specially for birds, white ants, butterflies, snails and squirrel, shows that trees in the homegardens was major habitat for faunal compositions. Living fence was a structural demarcation of the boundary provides live support and *Commiphora caudata* was the dominant tree species followed by *Thespesia populnea* and *Delonix elata* in live fences in Jaffna district (Jeyavanan *et al.*, 2014).

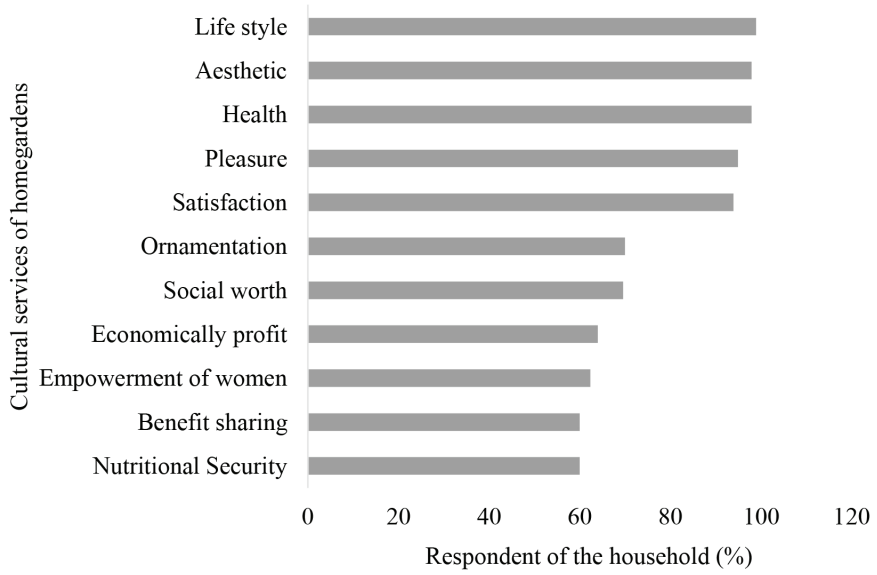

Figure 3: Percentage of household respondent for cultural services

Soil structure is enhanced through the activities of macro fauna such as earthworms, centipedes, millipedes, and isopods that aerate soil (Hendrix *et al.*, 1990) Homegardeners have been practicing several cultivation practices such as burning, harvesting of crop yield, planting, watering, pollarding and pruning of live fence startup the soil process. Abrupt environmental factors include wind, rainfall, flood and drought was recorded in the homegardens also leads to nutrient removal in the soil (Daily *et al.*, 1997). Enhancement of soil formation and nutrient cycling will leads to hasten the primary production through photosynthesis (Garbach *et al.*, 2014).

4. Conclusions

Jaffna homegardens provides all four category of ecosystem services namely, provisioning, regulating, cultural and supporting. Live fence structure and domestic animal rearing were the unique features of the Jaffna homegardens. Floristic diversity of the homegardens was equally distributed with medium species diversity and domestic faunal diversity was not equally distributed with low species diversity. Mean value of aboveground carbon stock was 40.51±3.67 Mg C ha^{-1}. Growing more number of fodder trees in the fence as living wall and grasses in the homegardens will meet the demand of fodder requirement for animals. Attractive landscape features, scientific advancement and research need to be addressed for cognitive development through the process of replacement, substitution, expansion and management in the peninsula.

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Prof. B. Marambe, Department of Crop Science, Faculty Agriculture, University of Peradeniya

Mrs. K. Nishanthan, Department of Agronomy, Faculty of Agriculture, University of Jaffna.

Dr.(Mrs.).L. Pradheeban, Department of Agronomy, Faculty of Agriculture, University of Jaffna

Mr. K. Prasannath, Department of Agricultural Biology, Faculty of Agriculture, Eastern University, Sri Lanka

Prof. K.L. Vasanthakumara, Department of Agriculture Biology, Faculty of Agriculture, University of Ruhuna, Sri Lanka

Dr. S. Vasantharuba, Department of Agricultural Chemistry, Faculty of Agriculture, University of Jaffna

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Length and Style: The length of the paper should not exceed 15 A4 pages. Minimum number of pages should be 6 A4 pages. The style of writing should conform to acceptable English usage.
Slang, jargon, unauthorized abbreviations, abbreviated phrasings and the like, should be avoided.

Manuscript Layout: Manuscript for article should be organized as follows: Title, Abstract, Keywords, Introduction, Materials and Methods, Results and Discussion, Conclusion, Acknowledgement and References. Pages should be numbered consecutively and arranged in the following order.

Page 1
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Page 2
Abstract: No more than 250 words for full length articles. The abstract should not contain any references and should be able to stand on its use without modification in abstracting journals. It should outline objectives and methodology together with important results and conclusions.

Keywords: A maximum of six keywords may include the name of an organism (common and scientific), method or other words or phrases that represent the subject of the study.

Page 3
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Materials and Methods:
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Conclusion

Unqualified statements and conclusions not completely supported by data should be avoided. All hypotheses should be clearly identified as such.

Acknowledgement

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Citation in the text

Cite references in the text by name and year in parentheses. Some examples:

…fully hydrogenated fats are blended with liquid oils as the feed stocks of interesterification (Zhang *et al.*, 2000).

…. with low or zero trans fatty acids and the results were promising (Zhang *et al.*, 2001; Zhang *et al.*, 2006; Goli *et al.*, 2008).

……trans-free margarine formulations and most widely used enzyme for the interesterification is Lipozyme TL IM (Ferreira-Dias, 2013).

…..fatty acids can be obtained by enzymatic interesterification (Huang and Akoh, 1994). This result was later contradicted by Becker and Seligman (1996).

Reference list

Journals articles

1. Single author

Gil, A. 2002. Polyunsaturated fatty acids and inflammatory diseases. Biomedicine and Pharmacotherepy, 56:388–396.

2. Two authors

Huang, K.H. and Akoh, C.C. 1994. Lipase-catalyzed incorporation of n-3 polyunsaturated fatty acids into vegetable oils. Journal of the American Oil Chemists' Society, 71:1277–1280.

3. More than two authors

Zhang, H., Xu, X., Mu, H., Nilsson, J., Adler-Nissen, J. and Høy, C.E. 2000. Lipozyme IM- catalyzed interesterification for the production of margarine fats in a 1 kg scale stirred tank reactor. European Journal of Lipid Science and Technology, 102:411–418.

Books and other monographs

4. Chapter in book

Gordon, M.H. 2001. The development of oxidative rancidity. In: Pokorny, J., Yanishlieva, N. and Gordon, M. (eds) Antioxidants in Food – Practical Applications. CRC Press, Washington, pp 7-225.

Web references

The full URL should be given with the date when the reference was last accessed. Any further information, if known (DOI, author names, dates, reference to a source publication, etc.), should also be given.

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