DAFTAR JURNAL YANG DIREVIEW OLEH Dr. MARINA SILALAHI, M.Si

No	Judul Artikel	Nama Jurnal, volume dan URL	Grade Jurnal
1	An Ethnobotanical Survey of a Dryland Botanical Garden and Its Environs in Kenya: The Mutomo Hill Plant Sanctuary	Evidence-Based Complementary and Alternative Medicine Volume 2020, Article ID 1543831, 22 pages; https://doi.org/10.1155/2020/1543831	Jurnal Internasional Bereputasi Q1 dengan H Indeks 72 dan SJR = 0,59
2	Ethnobotany of sugar palm (Arenga pinnata) in the Sasak Community, Kekait Village, West Nusa Tenggara, Indonesia	BIODIVERSITAS Volume 21, Number 1, Page 117-128 January 2020 https://smujo.id/biodiv/article/view/4554/3576	Jurnal Internasional Bereputasi Q3 dengan H Indeks 11 dan SJR = 0,27
3	Ethnobotanical investigation of spice and condiment plants used by the Taming tribe in Aceh, Indonesia	BIODIVERSITAS Volume 21, Number 10: Pages: 117-128 October 2020 https://smujo.id/biodiv/article/view/6380/4245	Jurnal Internasional Bereputasi Q3 dengan H Indeks 11 dan SJR = 0,27
4	Pathogenic activity of Fusarium equiseti from plantation of citrus plants (Citrus nobilis) in the village Tegal Wangi, Jember Umbulsari, East Java, Indonesia	Asian J Agri & Biol. 2017;5(4):202-213 https://www.asianjab.com/wp-content/uploads/2017/12/OA-AJAB-2017-06-053_OK.pdf	Jurnal Internasional Bereputasi Q4 dengan H Indeks 7 dan SJR = 0,16
5	Spectroscopic and morphological characteristics of genus Jatropha (Euphorbiaceae) and genus Jojoba (Simmondsiaceae)	Asian J Agri & Biol. 2017;5(4):280-290 https://www.asianjab.com/wp-content/uploads/2017/12/OA-AJAB-2017-07-086_OK.pdf	Jurnal Internasional Bereputasi Q4 dengan H Indeks 7 dan SJR = 0,16

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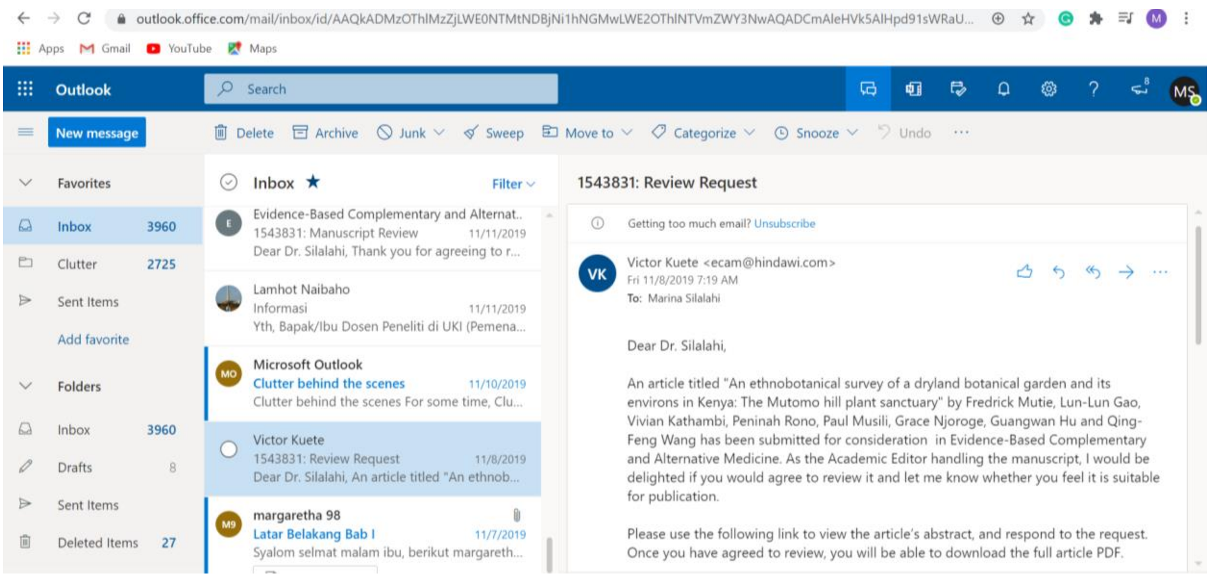

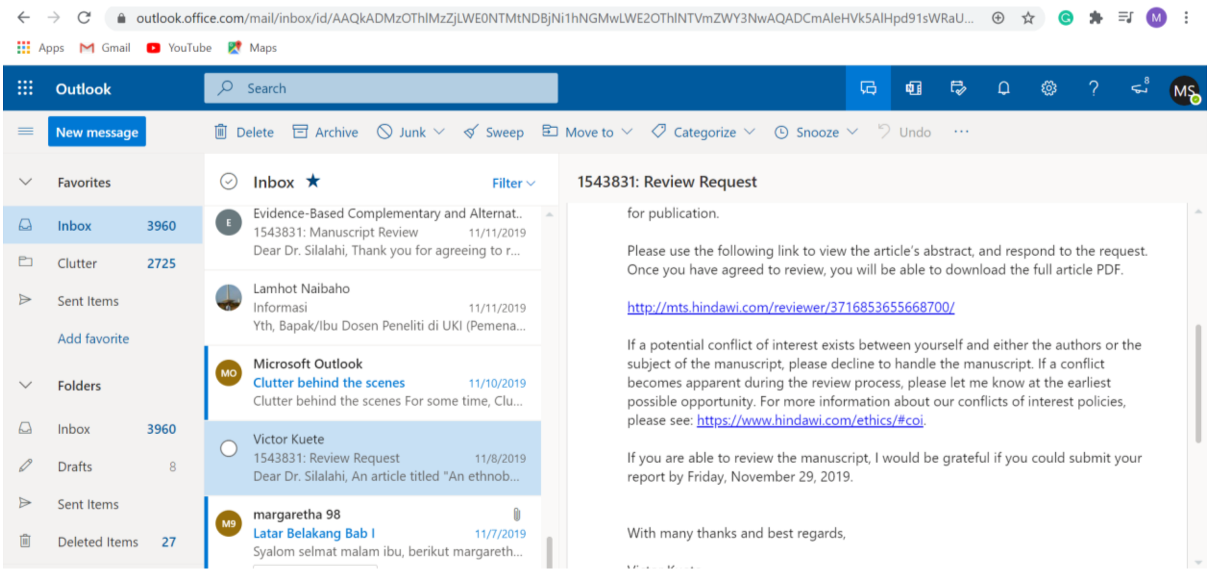

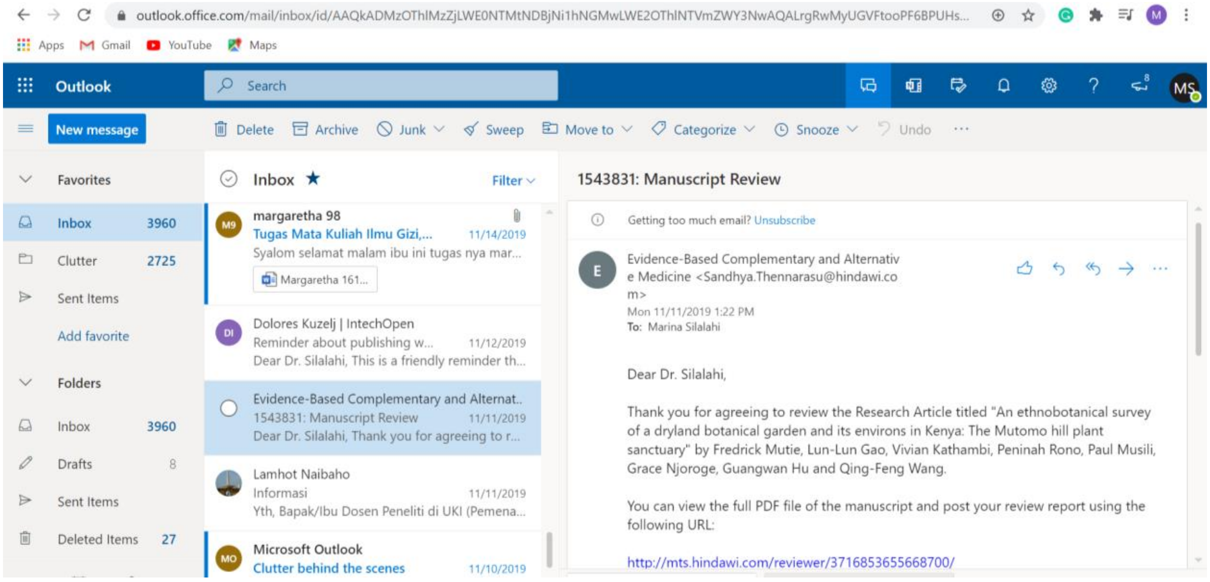

1543831: Manuscript Review

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Evidence-Based Complementary and Alternative Medicine <Sandhya.Thennarasu@hindawi.com>
Mon 11/11/2019 1:22 PM
To: Marina Silalahi

Dear Dr. Silalahi,

Thank you for agreeing to review the Research Article titled "An ethnobotanical survey of a dryland botanical garden and its environs in Kenya: The Mutomo hill plant sanctuary" by Fredrick Mutie, Lun-Lun Gao, Vivian Kathambi, Peninah Rono, Paul Musili, Grace Njoroge, Guangwan Hu and Qing-Feng Wang.

You can view the full PDF file of the manuscript and post your review report using the following URL:

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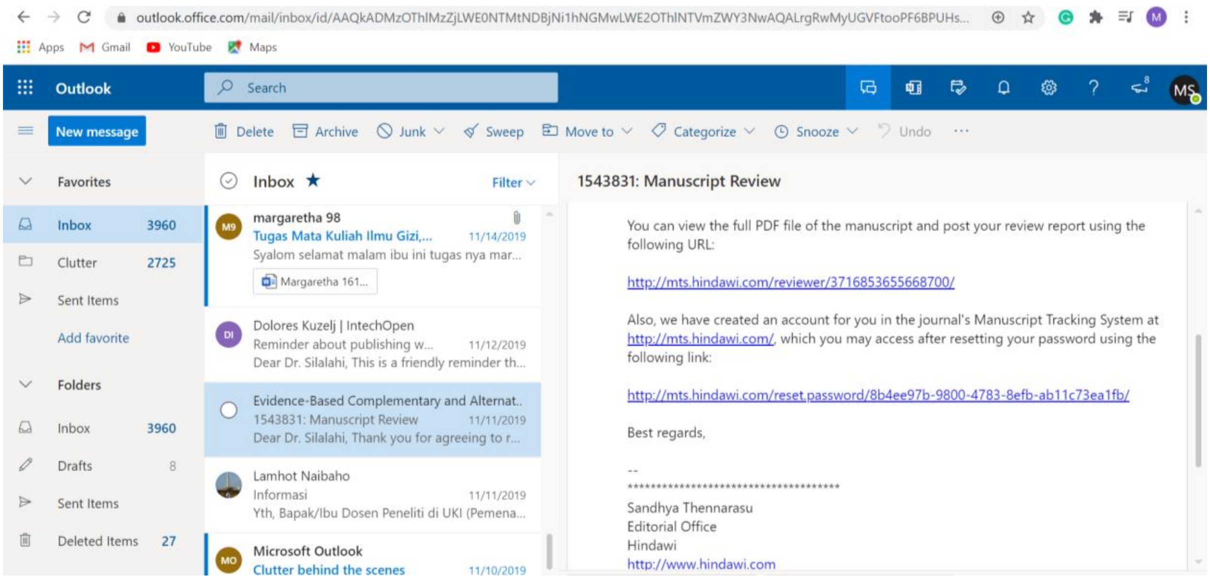

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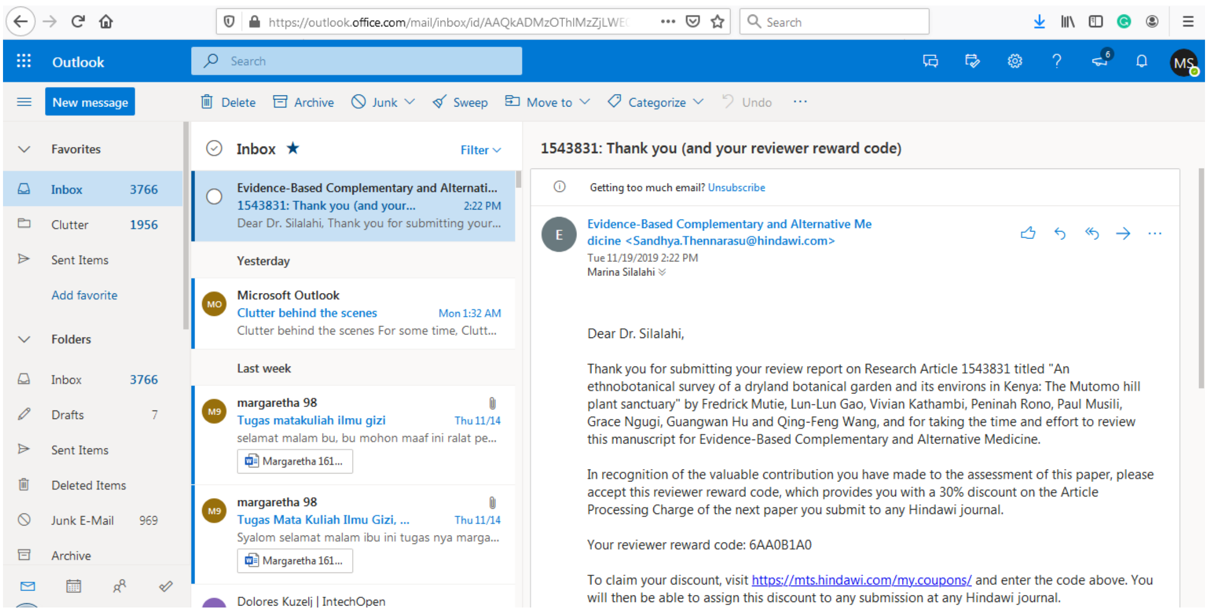

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Tue 11/19/2019 2:22 PM
Marina Silalahi

Dear Dr. Silalahi,

Thank you for submitting your review report on Research Article 1543831 titled "An ethnobotanical survey of a dryland botanical garden and its environs in Kenya: The Mutomo hill plant sanctuary" by Fredrick Mutie, Lun-Lun Gao, Vivian Kathambi, Peninah Rono, Paul Musili, Grace Ngugi, Guangwan Hu and Qing-Feng Wang, and for taking the time and effort to review this manuscript for Evidence-Based Complementary and Alternative Medicine.

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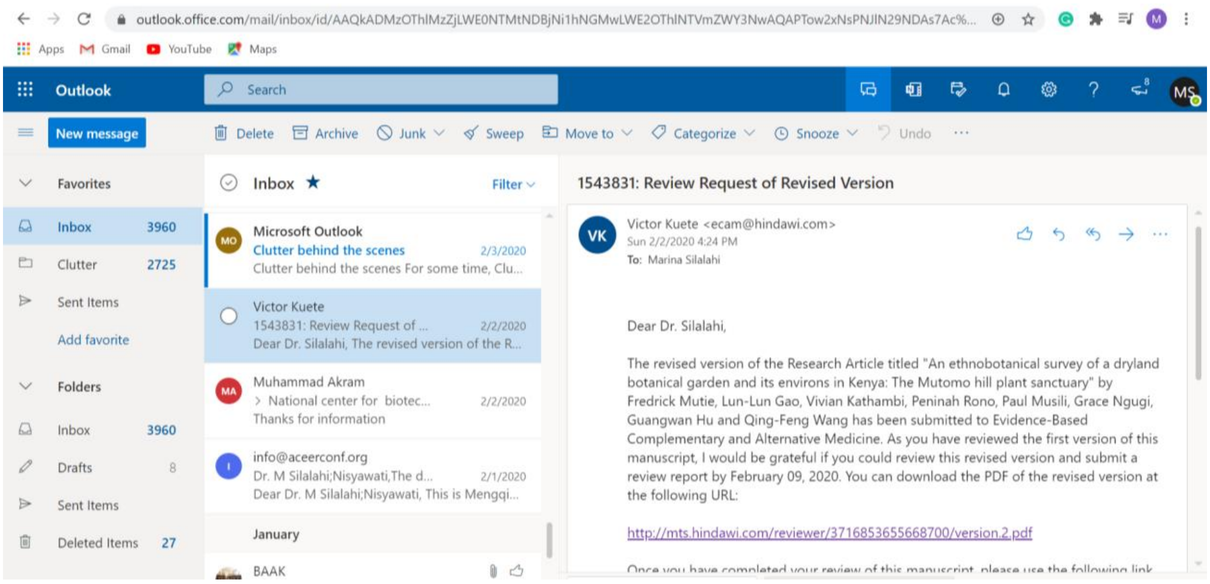

1543831: Review Request of Revised Version

Victor Kuete <ecam@hindawi.com>
Sun 2/2/2020 4:24 PM
To: Marina Silalahi

Dear Dr. Silalahi,

The revised version of the Research Article titled "An ethnobotanical survey of a dryland botanical garden and its environs in Kenya: The Mutomo hill plant sanctuary" by Fredrick Mutie, Lun-Lun Gao, Vivian Kathambi, Peninah Rono, Paul Musili, Grace Ngugi, Guangwan Hu and Qing-Feng Wang has been submitted to Evidence-Based Complementary and Alternative Medicine. As you have reviewed the first version of this manuscript, I would be grateful if you could review this revised version and submit a review report by February 09, 2020. You can download the PDF of the revised version at the following URL:

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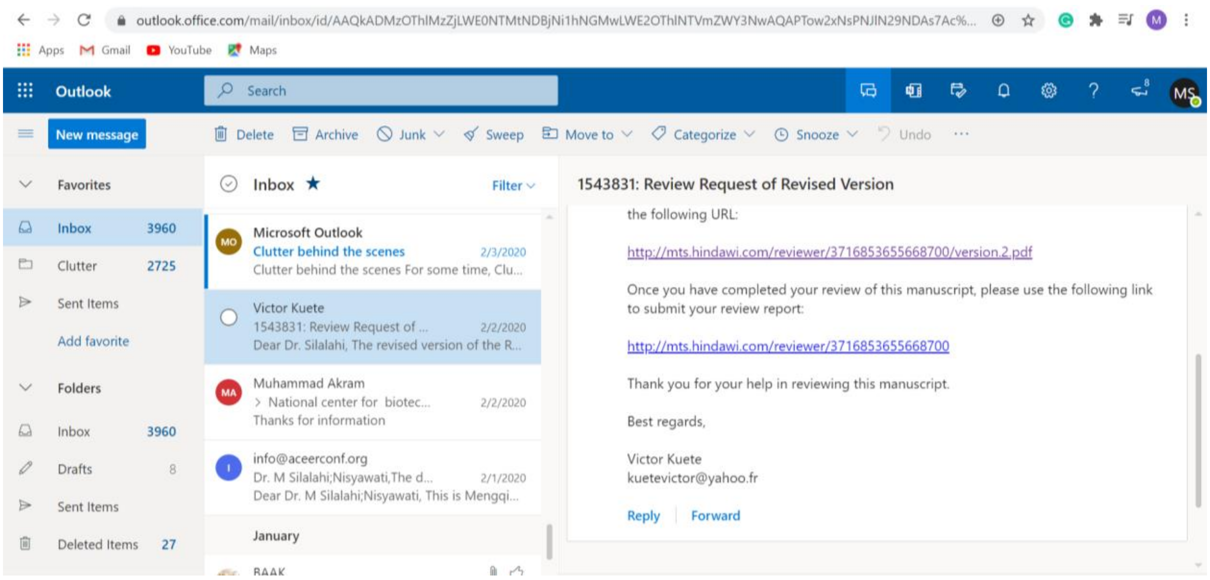

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Once you have completed your review of this manuscript, please use the following link to submit your review report:

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Thank you for your help in reviewing this manuscript.

Best regards,

Victor Kuete
kuetevictor@yahoo.fr

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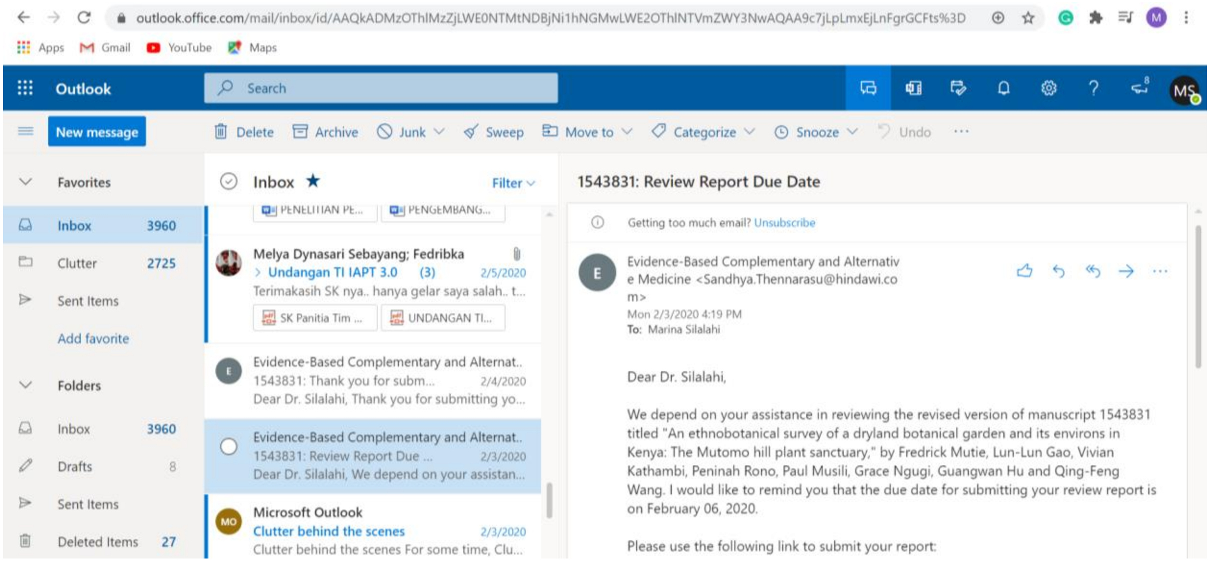

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Mon 2/3/2020 4:19 PM
To: Marina Silalahi
Dear Dr. Silalahi,
We depend on your assistance in reviewing the revised version of manuscript 1543831 titled "An ethnobotanical survey of a dryland botanical garden and its environs in Kenya: The Mutomo hill plant sanctuary," by Fredrick Mutie, Lun-Lun Gao, Vivian Kathambi, Peninah Rono, Paul Musili, Grace Ngugi, Guangwan Hu and Qing-Feng Wang. I would like to remind you that the due date for submitting your review report is on February 06, 2020.
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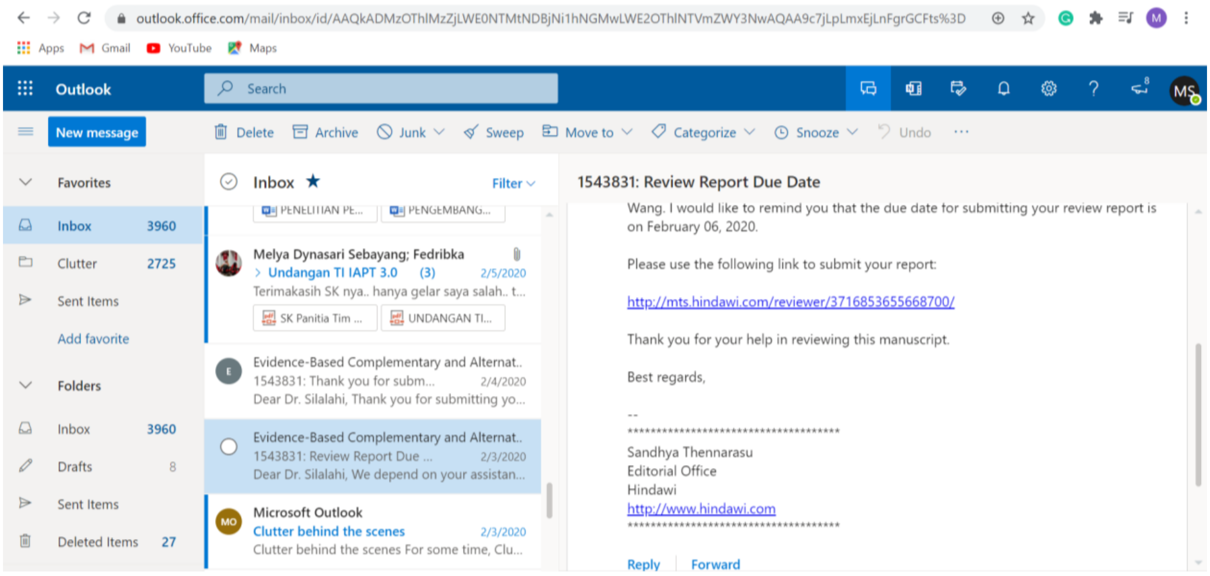

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Wang. I would like to remind you that the due date for submitting your review report is on February 06, 2020.
Please use the following link to submit your report:
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Thank you for your help in reviewing this manuscript.
Best regards,
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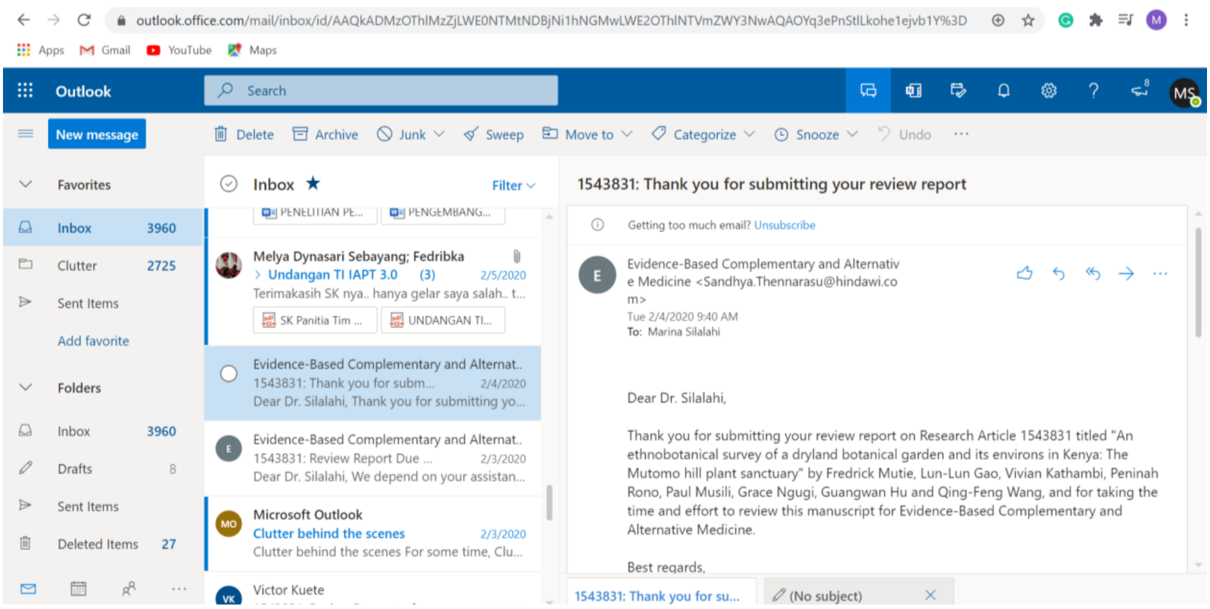
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Evidence-Based Complementary and Alternative Medicine <Sandhya.Thennarasu@hindawi.com>
Tue 2/4/2020 9:40 AM
To: Marina Silalahi
Dear Dr. Silalahi,
Thank you for submitting your review report on Research Article 1543831 titled "An ethnobotanical survey of a dryland botanical garden and its environs in Kenya: The Mutomo hill plant sanctuary" by Fredrick Mutie, Lun-Lun Gao, Vivian Kathambi, Peninah Rono, Paul Musili, Grace Ngugi, Guangwan Hu and Qing-Feng Wang, and for taking the time and effort to review this manuscript for Evidence-Based Complementary and Alternative Medicine.
Best regards,
1543831: Thank you for su...
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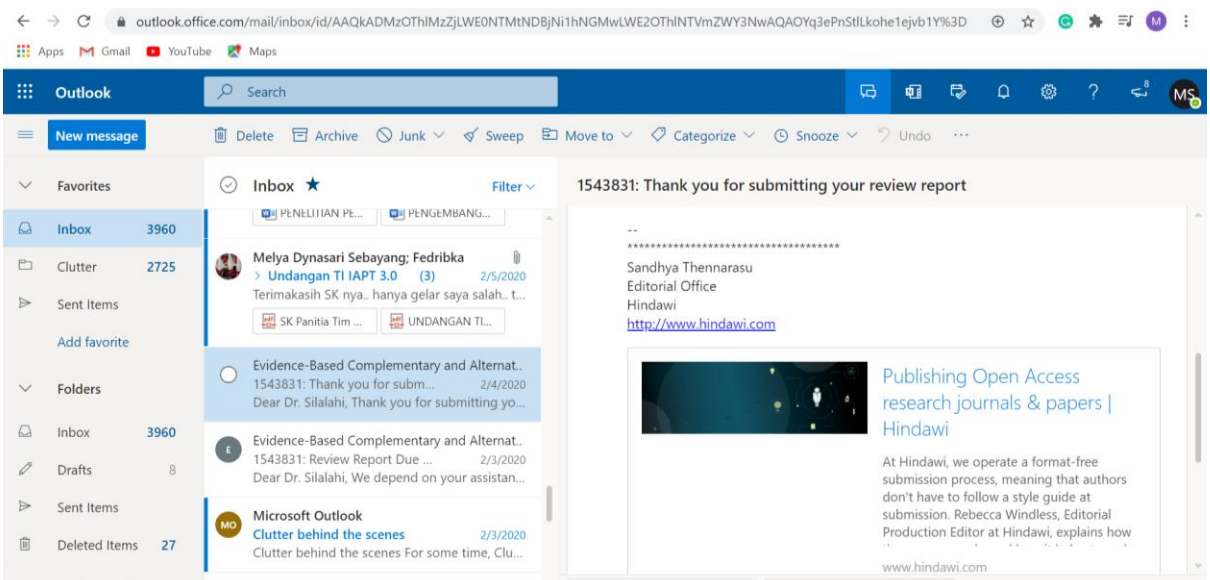
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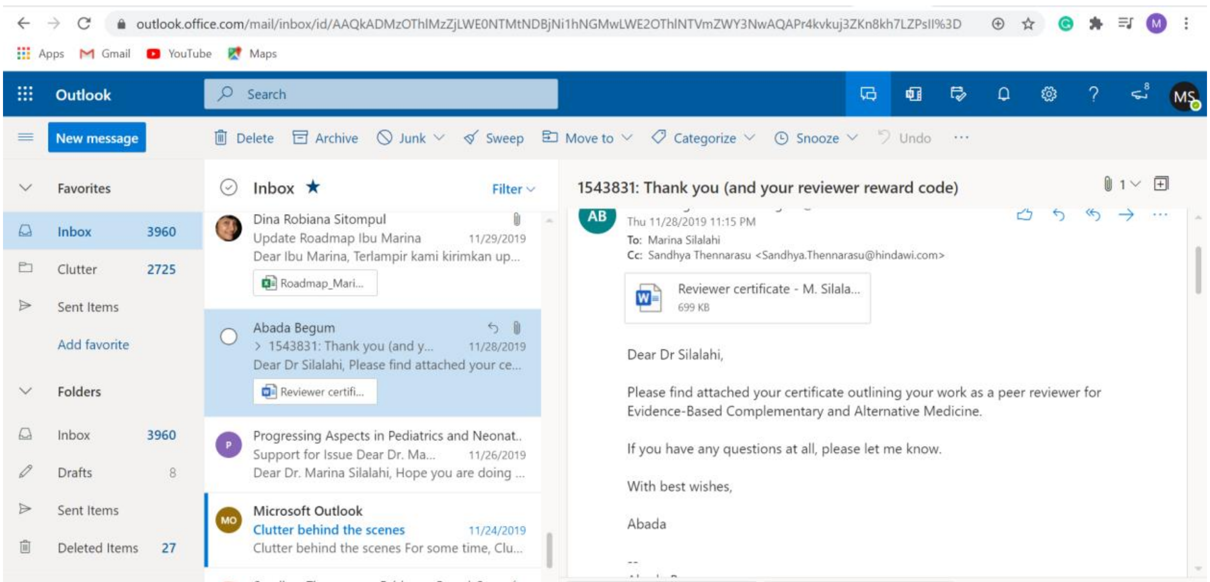
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Update Roadmap Ibu Marina 11/29/2019
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1543831: Thank you (and y... 11/28/2019
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1543831: Thank you (and your reviewer reward code)
Thu 11/28/2019 11:15 PM
To: Marina Silalahi
Cc: Sandhya Thennarasu <Sandhya.Thennarasu@hindawi.com>
Reviewer certificate - M. Silala...
699 KB
Dear Dr Silalahi,
Please find attached your certificate outlining your work as a peer reviewer for Evidence-Based Complementary and Alternative Medicine.
If you have any questions at all, please let me know.
With best wishes,
Abada

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28th November 2019

To whom it may concern,

This is to acknowledge that Dr. M. Silalahi has acted as a Peer Reviewer for *Evidence-Based Complementary and Alternative Medicine.*

*Evidence-Based Complementary and Alternative Medicine*is apeer reviewed, Open Access journal which publishes original research and review articles in relation tothe study of complementary and alternative medicine modalities, particularly traditional Asian healing systems.

The most recent Impact Factor for *Evidence-Based Complementary and Alternative Medicine* is 1.984 according to the 2018 Journal Citation Reports released by Clarivate Analytics in 2019. The journal's most recent Cite Score is 2.01 according to the Cite Score 2018 metrics released by Scopus.

Sincerely,

A.Begum

Abada Begum
Publishing Editor

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Evidence-Based Complementary and Alternative Medicine

Country	Egypt - SIR Ranking of Egypt
Subject Area and Category	Medicine Complementary and Alternative Medicine
Publisher	Hindawi Publishing Corporation
Publication type	Journals
ISSN	17414288, 1741427X
Coverage	2005-ongoing
Scope	Evidence-based Complementary and Alternative Medicine (eCAM) is an international, peer-reviewed journal that seeks to understand the sources and to encourage rigorous research in this new, yet ancient world of complementary and alternative medicine. The Journal seeks to apply scientific rigor to the study of complementary and alternative medicine (CAM) modalities, particularly traditional Asian healing systems. eCAM emphasizes health outcome, while

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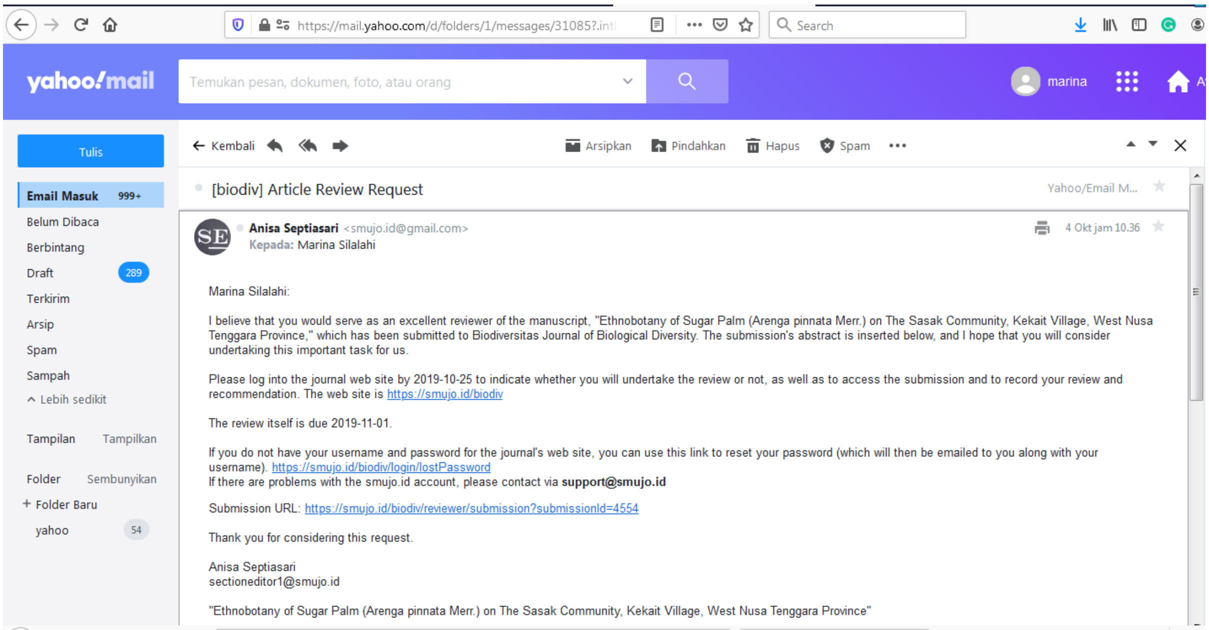
Etab Saleh AlGhamdi 10 months ago

Hi Editor,
I would like to publish my paper in 'evidence- Based Complementary and Alternative Medicine'. the tital of my paper is Protective effect of Quinoa seeds (Chenopodium Quinoa Willd.) against hypercholesterolemia in male rats

also I have some quetions
1- How much time it take to publish?

2. Ethnobotany of sugar palm (Arenga pinnata) in the Sasak Community, Kekait Village, West Nusa Tenggara, Indonesia: telah Terbit di Jurnal Jurnal BIODIVERSITAS Volume 21, Number 1, Page 117-128 (Terindeks scopus Q3) https://smujo.id/biodiv/article/view/4554/3576


[biodiv] Article Review Request

Anisa Septiasari <smujo.id@gmail.com>
Kepada: Marina Silalahi
4 Okt jam 10.36

Marina Silalahi:

I believe that you would serve as an excellent reviewer of the manuscript, "Ethnobotany of Sugar Palm (Arenga pinnata Merr.) on The Sasak Community, Kekait Village, West Nusa Tenggara Province," which has been submitted to Biodiversitas Journal of Biological Diversity. The submission's abstract is inserted below, and I hope that you will consider undertaking this important task for us.

Please log into the journal web site by 2019-10-25 to indicate whether you will undertake the review or not, as well as to access the submission and to record your review and recommendation. The web site is https://smujo.id/biodiv

The review itself is due 2019-11-01.

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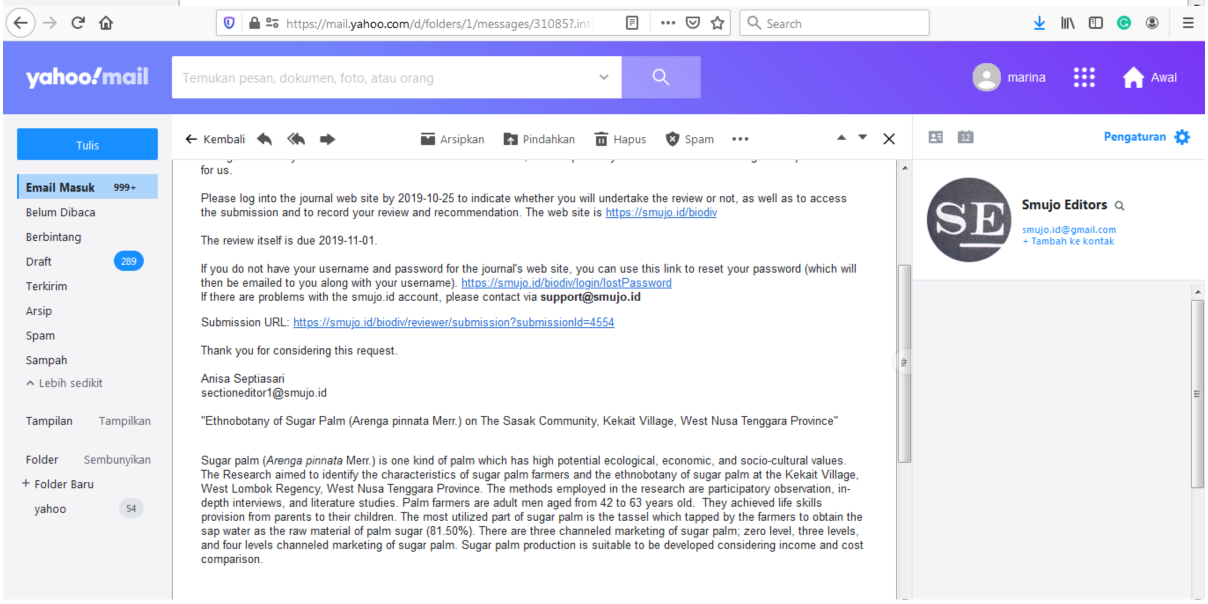
Submission URL: https://smujo.id/biodiv/reviewer/submission?submissionId=4554

Thank you for considering this request.

Anisa Septiasari
sectioneditor1@smujo.id

"Ethnobotany of Sugar Palm (Arenga pinnata Merr.) on The Sasak Community, Kekait Village, West Nusa Tenggara Province"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If there are problems with the smujo.id account, please contact via **support@smujo.id**

Submission URL: https://smujo.id/biodiv/reviewer/submission?submissionId=4554

Thank you for considering this request.

Anisa Septiasari
sectioneditor1@smujo.id

"Ethnobotany of Sugar Palm (Arenga pinnata Merr.) on The Sasak Community, Kekait Village, West Nusa Tenggara Province"

Sugar palm (*Arenga pinnata* Merr.) is one kind of palm which has high potential ecological, economic, and socio-cultural values. The Research aimed to identify the characteristics of sugar palm farmers and the ethnobotany of sugar palm at the Kekait Village, West Lombok Regency, West Nusa Tenggara Province. The methods employed in the research are participatory observation, in-depth interviews, and literature studies. Palm farmers are adult men aged from 42 to 63 years old. They achieved life skills provision from parents to their children. The most utilized part of sugar palm is the tassel which tapped by the farmers to obtain the sap water as the raw material of palm sugar (81.50%). There are three channeled marketing of sugar palm; zero level, three levels, and four levels channeled marketing of sugar palm. Sugar palm production is suitable to be developed considering income and cost comparison.

Smujo Editors
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[biodiv] Article Review Acknowledgement 2

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Smujo Editors <smujo.id@gmail.com> 23 Okt jam 06.33
Kepada: Marina Silalahi

Marina Silalahi:

Thank you for completing the review of the submission, "Ethnobotany of Sugar Palm (Arenga pinnata Merr.) on The Sasak Community, Kekait Village, West Nusa Tenggara Province," for Biodiversitas Journal of Biological Diversity. We appreciate your contribution to the quality of the work that we publish.

Smujo Editors
editors@smujo.id

Biodiversitas Journal of Biological Diversity

marina Silalahi Dear Editor If permitted, please give me a certificate reviewing this article. Best Reg: 12 Nov jam 11.35

Balas, **Balas ke Semua** atau **Teruskan**

Biodiversitas

Country	Indonesia - SIR Ranking of Indonesia
Subject Area and Category	Agricultural and Biological Sciences Animal Science and Zoology Plant Science Biochemistry, Genetics and Molecular Biology Molecular Biology
Publisher	Biology department, Sebelas Maret University Surakarta - SCImago Institutions Ranking
Publication type	Journals
ISSN	1412033X, 20854722
Coverage	2014-2020

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H Index

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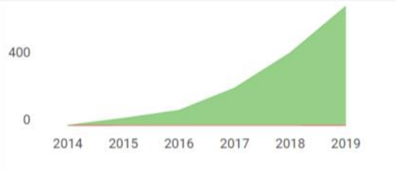

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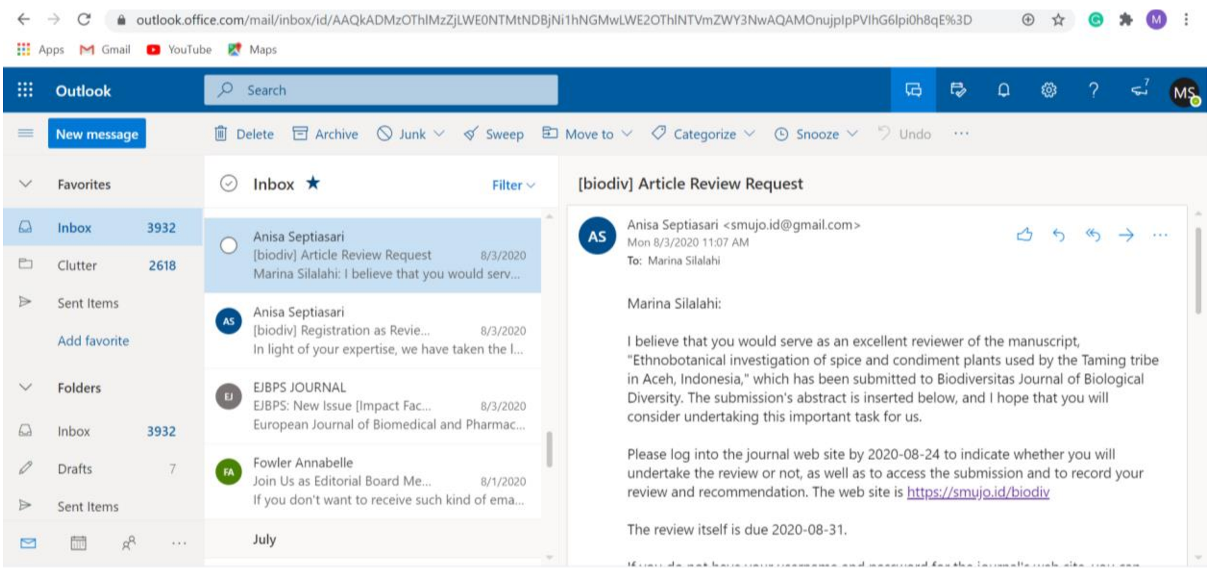

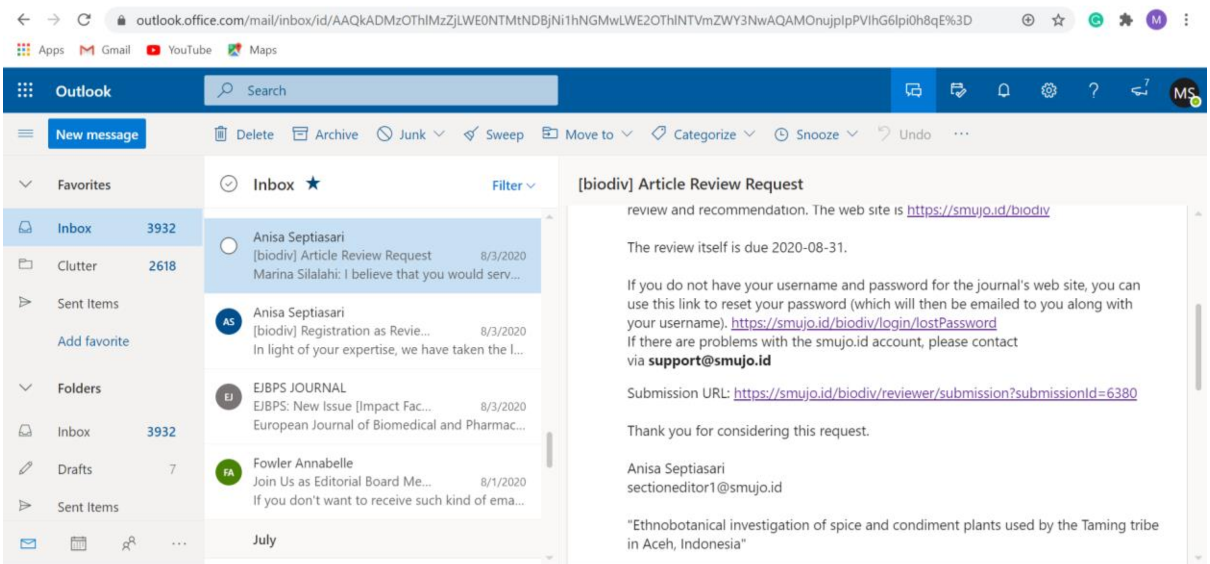

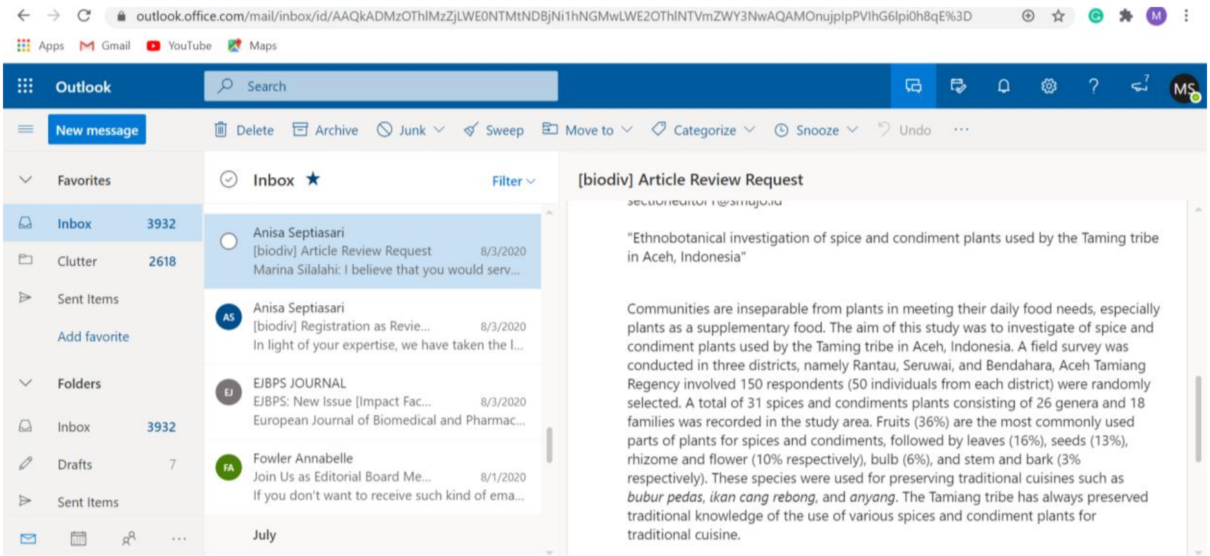

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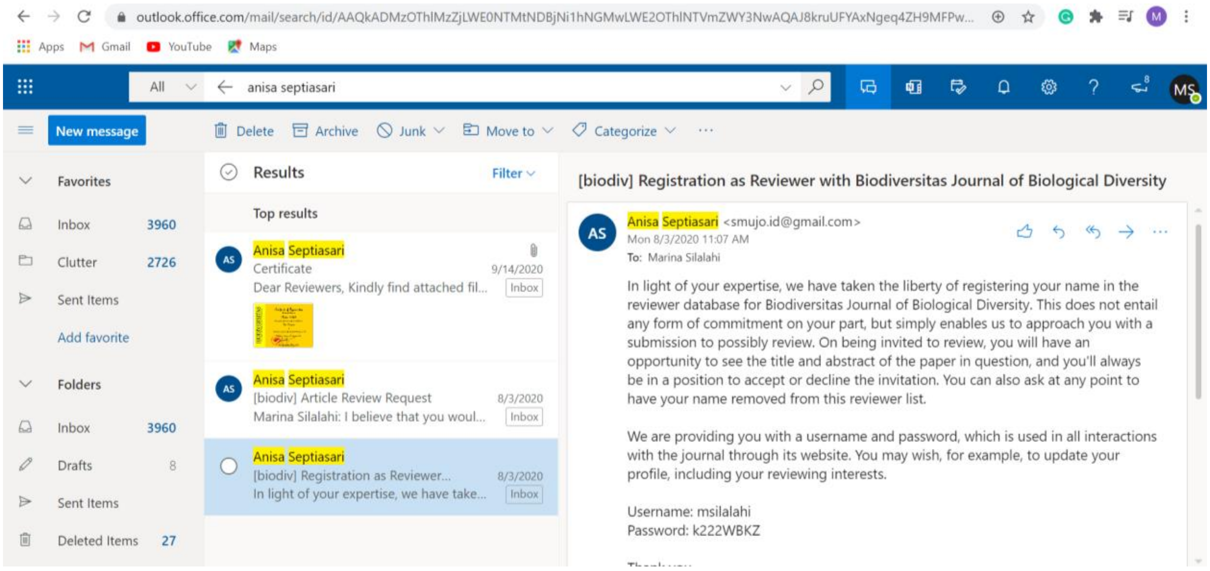
"Ethnobotanical investigation of spice and condiment plants used by the Taming tribe in Aceh, Indonesia"
Communities are inseparable from plants in meeting their daily food needs, especially plants as a supplementary food. The aim of this study was to investigate of spice and condiment plants used by the Taming tribe in Aceh, Indonesia. A field survey was conducted in three districts, namely Rantau, Seruwai, and Bendahara, Aceh Tamiang Regency involved 150 respondents (50 individuals from each district) were randomly selected. A total of 31 spices and condiments plants consisting of 26 genera and 18 families was recorded in the study area. Fruits (36%) are the most commonly used parts of plants for spices and condiments, followed by leaves (16%), seeds (13%), rhizome and flower (10% respectively), bulb (6%), and stem and bark (3% respectively). These species were used for preserving traditional cuisines such as *bubur pedas*, *ikan cang rebong*, and *anyang*. The Tamiang tribe has always preserved traditional knowledge of the use of various spices and condiment plants for traditional cuisine.



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Prof. Drs. Sutarno, M.Sc., Ph.D.
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4. Pathogenic activity of Fusarium equiseti from plantation of citrus plants (Citrus nobilis) in the village Tegal Wangi, Jember Umbulsari, East Java, Indonesia: Telah terbit di Asian J Agri & Biol. 2017;5(4):202-213. https://www.asianjab.com/wp-content/uploads/2017/12/OA-AJAB-2017-06-053_OK.pdf

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Asian Journal of Agriculture and Biology <ajab@ejmanager.com> — Rab, 21 Jun 2017 jam 15.10
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ABSTRACT:
Fungus is a ubiquitous decompose and parasite associated with fruit and dead or dying plant tissues that also may be a pathogen on a wide range of agricultural plants. The objective of this work are isolation, identification and pathogenic assay fungi from citrus fruit plantations (Citrus nobilis), Tegal Wangi, Jember, Jawa Timur. Isolation of fungi using the washing method, smear agar method, and direct method. Samples were taken in the form of stems and leaves from citrus fruit plantation land in Tegal Wangi, Jember, East Java; Pathogenicity testing (the level of virulence of mold) was obtained using the Koch's postulates method; A total of 34 molds isolates were obtained. The color of colonies of 7-day-old cultures on PDA dominated with white, while the reverse was whitish to pale yellow. Based on the pathogenicity test, four representative mold isolates were identification of pathogenic fungi using the sequence of internal transcribed regions Spacer (ITS) in the region of ribosomal DNA selected and identified based on the sequence analyses of internal transcribed spacer (ITS) regions of rDNA. The molds were identified as: D5K3A (Fusarium equiseti with 98% homology bootstrap value 64), D6. K3.B (Fusarium equiseti with 99% homology bootstrap value of 100%), D7.K2.B (Fusarium equiseti with 99% homology bootstrap value 99%) and D3.K2.B (Fusarium equiseti with 99% homology bootstrap value of 88%). Fusarium equiseti is a main source of trichothecenes, zearalenone and other mycotoxins which can cause serious disease in human and animal. This information regarding the Fusarium equiseti cause damage to the leaves of citrus can be used for important information about the occurrence of pathogenic fungi in citrus fruit plantations.

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Asian Journal of Agriculture and Biology <ajab@ejmanager.com> Rab, 5 Jul 2017 jam 15.16
Kepada: marina_biouki@yahoo.com

Jul 05, 2017

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On behalf of the Editorial Board of the Asian Journal of Agriculture and Biology, we appreciate the voluntary contribution that each reviewer gives to the Journal. We thank you for your participation in the online review process and hope that we may call upon you again to review future manuscripts.

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Kepada: marina_biouki@yahoo.com
Cc: marina.silalahi@uki.ac.id

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Dear Dr. Marina Silalahi,

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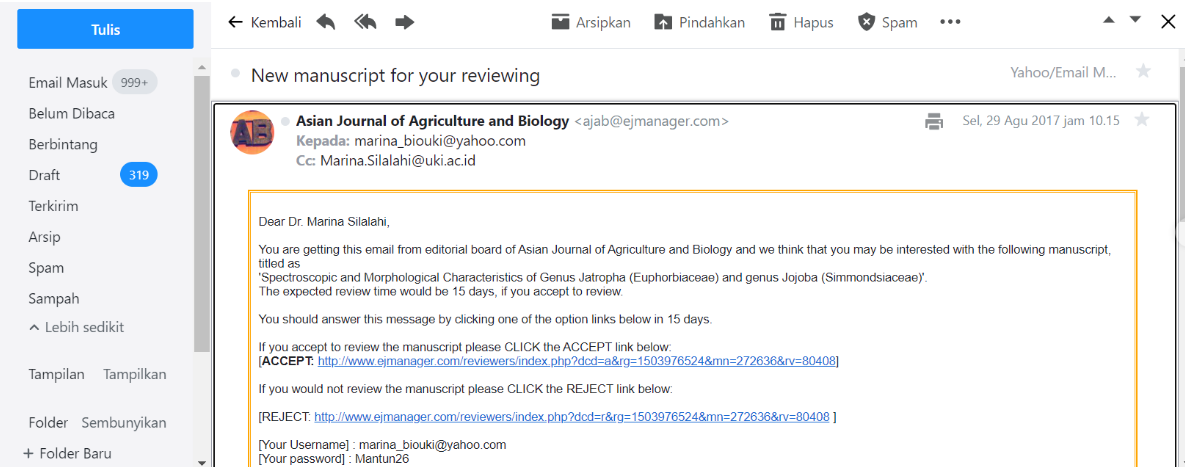

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Kepada: marina_biouki@yahoo.com

Cc: Marina.Silalahi@uki.ac.id

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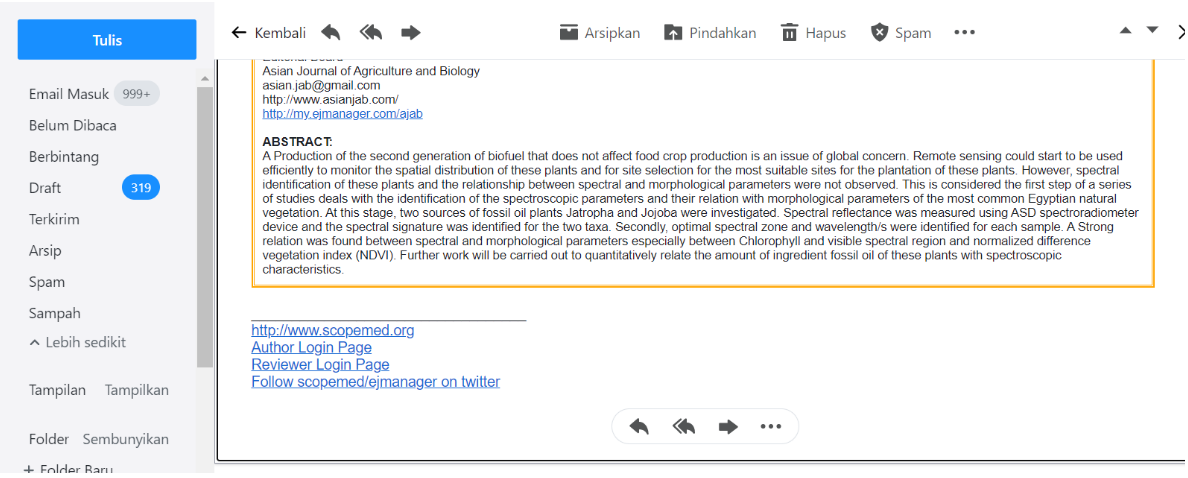

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ABSTRACT:
A Production of the second generation of biofuel that does not affect food crop production is an issue of global concern. Remote sensing could start to be used efficiently to monitor the spatial distribution of these plants and for site selection for the most suitable sites for the plantation of these plants. However, spectral identification of these plants and the relationship between spectral and morphological parameters were not observed. This is considered the first step of a series of studies deals with the identification of the spectroscopic parameters and their relation with morphological parameters of the most common Egyptian natural vegetation. At this stage, two sources of fossil oil plants Jatropha and Jojoba were investigated. Spectral reflectance was measured using ASD spectroradiometer device and the spectral signature was identified for the two taxa. Secondly, optimal spectral zone and wavelength/s were identified for each sample. A Strong relation was found between spectral and morphological parameters especially between Chlorophyll and visible spectral region and normalized difference vegetation index (NDVI). Further work will be carried out to quantitatively relate the amount of ingredient fossil oil of these plants with spectroscopic characteristics.

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Asian Journal of Agriculture and Biology <ajab@ejmanager.com> Sel, 12 Sep 2017 jam 12.23
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Sep 12, 2017

Dear Marina Silalahi,

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Cc: Marina.Silalahi@uki.ac.id

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Dear Dr. Marina Silalahi,

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ABSTRACT:
A Production of the second generation of biofuel that does not affect food crop production is an issue of global concern. Remote sensing could start to be used efficiently to monitor the spatial distribution of these plants and for site selection for the most suitable sites for the plantation of these plants. However, spectral identification of these plants and the relationship between spectral and morphological parameters were not observed. This is considered the first step of a series of studies deals with the identification of the spectroscopic parameters and their relation with morphological parameters of the most common Egyptian natural vegetation. At this stage, two sources of fossil oil plants Jatropha and Jojoba were investigated. Spectral reflectance was measured using ASD spectroradiometer device and the spectral signature was identified for the two taxa. Secondly, optimal spectral zone and wavelength/s were identified for each sample. A Strong relation was found between spectral and morphological parameters especially between Chlorophyll and visible spectral region and normalized difference vegetation index (NDVI). Further work will be carried out to quantitatively relate the amount of ingredient fossil oil of these plants with spectroscopic characteristics.

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Volume 2020, Article ID 1543831, 22 pages
https://doi.org/10.1155/2020/1543831

Research Article

An Ethnobotanical Survey of a Dryland Botanical Garden and Its Environs in Kenya: The Mutomo Hill Plant Sanctuary

Fredrick Munyao Mutie,[1,2,3] **Lun-Lun Gao**,[1,2] **Vivian Kathambi**,[1,2,3] **Peninah Cheptoo Rono**,[1,2,3] **Paul Mutuku Musili**,[4] **Grace Ngugi**,[4] **Guang-Wan Hu**,[1,2] **and Qing-Feng Wang**[1,2]

[1]*CAS Key Laboratory of Plant Germplasm Enhancement and Speciality Agriculture, Wuhan Botanical Garden, Chinese Academy of Sciences, Wuhan 430074, China*
[2]*Sino-Africa Joint Research Center, Chinese Academy of Sciences, Wuhan 430074, China*
[3]*University of Chinese Academy of Sciences, Beijing 100049, China*
[4]*East Africa Herbarium, National Museums of Kenya, P.O. Box 451660-0100, Nairobi, Kenya*

Correspondence should be addressed to Guang-Wan Hu; guangwanhu@wbgcas.cn

Received 3 November 2019; Revised 30 January 2020; Accepted 10 February 2020; Published 17 March 2020

Academic Editor: Victor Kuete

Mutomo hill plant sanctuary is a ten-hectare piece of land in Kenya listed as a botanical garden under the Botanical Gardens Conservation International, originally established in 1964 with the aim of conserving indigenous flora from destructive anthropogenic activities. This paper presents ethnobotanical documentation of medicinal plants of Mutomo hill plant sanctuary and its environs. An ethnobotanical survey was carried out in Mutomo hill plant sanctuary and its environs with 48 herbalists aged between 32 and 96 years from July 2018 to February 2019 using a semistructured open-ended questionnaire. The plants were collected through random surveys with each herbalist in different ecotypes around the villages and within the Mutomo hill plant sanctuary. The Relative Frequency of Citation (RFC) for each species reported was calculated to determine the plant species frequently collected. In total, 68 different plant species distributed in 28 families and 54 genera were reported. The frequently used plant families were Leguminosae (13 species), Lamiaceae (6 species), and Euphorbiaceae (6 species). Shrubs (37%) and trees (34%) were the dominant growth habits reported. The most cited plant species were *Cassia abbreviata* Oliv. (RFC = 0.63), *Acacia nilotica* (L.). Delile (RFC = 0.54), *Strychnos heningsii* Gilg (RFC = 0.46), and *Aloe secundiflora* Engl. (RFC = 0.31). Root (19 species) and bark (19 species) were the frequently collected plant parts. Infectious diseases (33) and digestive system disorders (24) were reported to be managed with the majority of the plant species. This study contributes to safeguarding the traditional knowledge on medicinal plants in the study area, which is useful in appreciating and acknowledging the cultural heritage of the Kamba people from the local perspective of Mutomo area in Kenya. It also adds to the knowledge base and documentation of medicinal plants, which is useful information as potential data for drug development.

1. Introduction

The use of plants for medicine has been practiced for many years [1]. This culture has developed through trial and error and has for a long time been passed orally from one generation to another [1, 2]. African traditional medicine is the oldest, perhaps the most diverse mode of treatment and among the less known systems of medicine in the world [2–5]. Despite the production of synthetic drugs, the utilization of natural organic healing materials for the treatment of diseases has persisted throughout the world [5]. In addition, modern healthcare techniques have been less effective in the treatment of some infectious diseases such as malaria and HIV/AIDS which have affected Africa more than any other part of the world [6]. Furthermore, the use of traditional medicine has been attributed to the high cost and inaccessibility of modern healthcare care services compared to the cheap and readily available herbal medicine [6, 7]. The traditional communities have recently begun to appreciate the effectiveness of modern healthcare services against diseases such as HIV/AIDS leading to a reduction in the number of people relying on traditional medicine [8]. A recent study reported that the use of traditional medicine for health care has declined in Africa and Asia with most of the people turning to modern health care services. For example, just 1.7% and 1.5% of the populations studied in South Africa and Ghana respectively reported consulting traditional medical practitioners in the past three years [9]. An overall decline in the use of traditional practices has also been reported elsewhere in South Africa where an analysis of nationally representative population-based surveys from 1995 to 2007 showed that the use of traditional medicine had declined to 0.1% or less in the past month from 3.6–12.7% in just over a decade [10]. It has been estimated that at least 90% of the population in Kenya has used medicinal plants for health care at some point in life [11]. However, Awiti [12] reported that only 7.56% of the respondents studied consulted "nonmodern" health care providers while just 0.15% consulted traditional healers, further suggesting that the use of traditional medicine is also on the decline in Kenya. The reduction in the use of traditional medicine is probably due to the increase and cultural acceptability of modern health care services [10]. Ethnomedicinal studies in East Africa have however revealed that medicinal plants are used by many populations for various health problems such as reproductive and gynecological problems [13, 14], management of infectious diseases such as HIV/AIDS and malaria [15–17] and as antidotes against snake bites [18, 19]. In addition, medicinal plants are sold in some urban areas as a source of income [20, 21].

In Kenya, about 80% of the landmass is covered by arid and semiarid areas [22]. Drylands of Kenya play a significant role in the country's formal and informal economy, yet they have not been incorporated in the country's conservation regimes making it difficult to get a true picture of their status and trends of their biodiversity. In addition, little support and advocacy have been directed to such areas [23]. Based on the Flora of Tropical East Africa, the flora of Kenya is comprised of 6,293 indigenous vascular plant species [24] out of which over 5,000 plant species reportedly occur in drylands [25]. An estimated 1,200 plant species in Kenya are reported to have a medicinal value [26]. In Kenya, ethnobotanical studies involving various ethnic groups have been done [16, 17, 21, 27–44]. The local communities who use natural resources have interacted with the biodiversity over the years and hence have accumulated important traditional knowledge regarding their use [40]. The aging of the older generations and the change of lifestyles that have seen the younger generations take up formal education have left much of the indigenous knowledge undocumented and on the verge of being lost [45]. In addition, ethnobotanical surveys have not been done extensively in many regions of Kenya [36]. There is therefore a need for appropriate measures to mitigate the current abuse and foster proliferation of the biodiversity in drylands for the benefit of future generations [46].

Like in many other African countries, medicinal plants in Kenya are commonly collected from the wild with poor harvesting methods such as debarking [47]. Such plants are diminishing as a result of unsustainable harvesting and destruction of habitats [48]. It is on account of such destructive human activities that the early botanists in Kenya considered the need to set aside areas for conservation of important indigenous plant species. Among such areas is the Mutomo hill plant sanctuary which was established in 1964 [49] and gazetted as a botanical garden in 1993 [50]. Despite this, plant diversity loss in such areas is still in progress and is expected to increase with the increase in the human population [46]. The Kenyan wealth of dryland biodiversity and its indigenous knowledge is not well documented [23]. There are various botanical surveys done in Kitui county such as the biodiversity of Kitui hills [46], some ethnobotanical surveys [34, 40] and a checklist of the vascular plants of Mutomo hill plant sanctuary [49]. Mutomo hill plant sanctuary is a well-known botanical garden under the Botanical Gardens Conservation International [50, 51]. Despite this, ethnobotanical surveys in Mutomo hill plant sanctuary and its environs have not been done. Since the role of botanical gardens in the conservation of useful plants including medicinal plants is well-known [52], the lack of ethnobotanical data of the sanctuary and its environs justified the need for this investigation. This study brings more understanding of medicinal plant usage and knowledge thereof to the nation as cultural and scientific heritage at a local level. It also informs about plants of economic importance to the world because it adds knowledge of these medicinal plants as potential resources for drug development.

2. Subjects and Methods

2.1. Study Area. The study was carried out in Mutomo hill plant sanctuary and its environs. Mutomo hill plant sanctuary is geographically located within the Mutomo division; hence Mutomo division was selected to represent the environs of Mutomo hill plant sanctuary. Mutomo division is located at 38°12′ East and 1°50′ South in Kitui county (Figure 1). Kitui county is largely a low plateau rising from 300 m above the sea level and interrupted by various inselbergs reaching about 1638 m above the sea level [53] where the highest altitudes reach about 1800 m [54]. Generally, the climate of Kitui county varies from arid to semiarid and is characterized by a minimum mean annual temperature varying from 14°C to 22°C and a maximum mean annual temperature ranging from 26°C to 34°C. There are two rainy seasons where the long rains start from March and end in June while the short rains start in October and end in December with a mean annual rainfall ranging from 250 mm to 1050 mm [54]. The low-lying areas receive low rainfall and are extremely hot. The vegetation of Kitui county is characterized by low, stunted, dense thorn bushes with thick undergrowth and occasional baobab trees. Much of the area lacks forests except on the hills [55] where scrublands and wooded bushlands can be found [56] dominated by *Drypetes*, *Combretum*, *Vepris,* and *Croton* species [46]. The geography of Kitui county is characterized by several

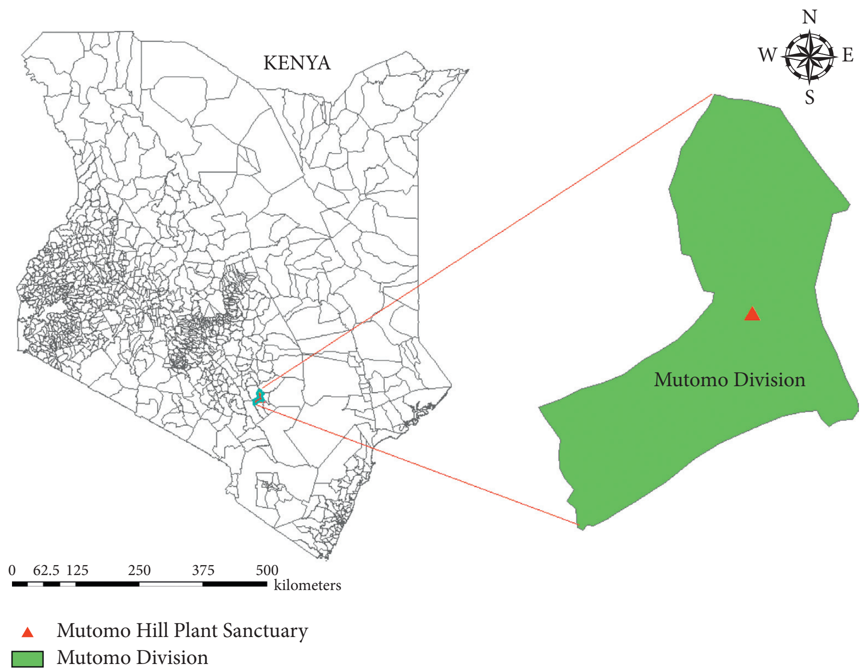

Figure 1: Map of Kenya showing the location of Mutomo division and Mutomo hill plant sanctuary.

hilltops which contain a high diversity of plant and animal species [46]. Such highlands provide a link between the coastal forests and the highland forests, resulting in the survival of unique species adapted to the individual highlands [46, 57]. One of such important highlands is the Mutomo hill plant sanctuary, located 125 miles East of Nairobi. The sanctuary is a ten-hectare piece of land, about 1211 m in length and rising to an altitude of about 1000 m from red lateritic plains to worn granitic gneiss [49, 50]. Its floral diversity is rich and includes succulent and xerophytic plants [49]. The plant diversity of Kitui county is high and is used by the local communities for traditional foods, tisanes, medicines among other uses [53, 57].

Kitui county is inhabited by Kamba people who practice agriculture and semipastoralism [40, 55] which involves growing a variety of crops and keeping livestock [53, 57] where the cattle are kept as a security against famine [58]. Most of the population in the county relies on agriculture for economic income, where the main food crops include maize, millet, sorghum, green grams, beans, peas, cassava, and sweet potatoes [54]. Literature reveals that as early as 1911, the Kitui Kamba traditional way of life was being interrupted by foreign groups including the colonial governments [58]. Despite this, they have conserved their indigenous knowledge on plant utilization and are reportedly one of the ethnic groups in Kenya who have conserved their traditional knowledge on medicinal plants [40, 53].

2.2. Ethnobotanical Data Collection and Analysis. The field survey was conducted between July 2018 and February 2019. Prior to the field survey, the herbal practitioners were identified with the help of the local administrative authorities who included the subchiefs of Mutomo division and the rangers at Mutomo hill plant sanctuary. In addition, the herbalists recommended the researchers to other herbalists within the study area. The informants were the herbalists who were practicing traditional medicine at the time of study or those who had reduced working periods due to age or to be involved in other activities such as farming. Interviews were administered in Kamba language, which is the main dialect spoken in the area and later translated into English. Interviews were recorded in semistructured open-ended questionnaires at the homesteads of the herbalists while in some cases, the herbalists met with the researchers at shopping centers or in other appropriate places such as farmlands where some of them collected the medicinal plants. The herbalists first mentioned the medicinal plants they had used and later guided the researchers to the wild where the plants were collected. Interviews with each informant lasted between two to five hours involving field surveys in different ecotypes including hills, forests, and farmlands throughout the six sublocations of Mutomo division and within the Mutomo hill plant sanctuary. Data collected included the demographic information of the informant (name, age, sex, occupation, and level of education) and the botanical information (vernacular name of the plant, its source, parts used, medicinal uses, and methods of drug preparation and administration). For each plant species cited, an herbarium voucher material was collected. Photographs of all the medicinal plants cited were taken to help during identification. Identification was done following the local monographs of the Kenyan flora [59, 60] and the Flora of Tropical East Africa [61]. The voucher collections were later verified at the East African (EA) herbarium in Kenya. All the voucher materials reported in this study were deposited at the EA (the collection details: localities, voucher numbers, elevation, and coordinates at sampling points are summarized in Table 1). The nomenclature of all the species

Table 1: A summary of the collection details of the voucher materials cited by the herbalists at Mutomo hill plant sanctuary and its environs.

Family and species name	Voucher number	Area of collection	Elevation and coordinates
Acanthaceae			
Barleria eranthemoides	Mutie MU0215	Kitoo sublocation, Ndiini village	836 m, 1°55′20.4″ S, 38°07′11.2″ E
Amaranthaceae			
Achyranthes aspera var. *sicula*	Mutie MU0192	Kawelu sublocation, Ngomeni village	713 m, 1°49′49.8″ S, 38°12′23.0″ E
Anacardiaceae			
Lannea schweinfurthii	Mutie MU0271	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Apiaceae			
Steganotaenia araliacea	Mutie MU0243	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Apocynaceae			
Calotropis procera	Mutie MU0238	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Edithcolea grandis	Mutie MU0216	Kitoo sublocation, Ndiini village	836 m, 1°55′20.4″ S, 38°07′11.2″ E
Asparagaceae			
Sansevieria perrotii	Mutie MU0063	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Burseraceae			
Commiphora baluensis	Mutie MU0190	Kawelu sublocation	713 m, 1°49′49.8″ S, 38°12′23.0″ E
Commiphora edulis	Mutie MU0193	Kawelu sublocation	713 m, 1°49′49.8″ S, 38°12′23.0″ E
Commiphora habessinica	Mutie MU0174	Kitoo sublocation	836 m, 1°54′46.1″ S, 38°11′00.9″ E
Capparaceae			
Boscia coriacea	Mutie MU0222	Kawelu sublocation	705 m, 1°47′12.3″ S, 38°14′19.5″ E
Maerua endlichii	Mutie MU0201	Kibwea sublocation	705 m, 1°47′12.3″ S, 38°14′19.5″ E
Combretaceae			
Combretum hereroense	Mutie MU0203	Kibwea sublocation	676 m, 1°44′09.9″ S, 38°13′36.0″ E
Terminalia brownii	Mutie MU0226	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Terminalia prunioides	Mutie MU0091	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Compositae			
Aspilia pluriseta	Mutie MU0225	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Kleinia squarrosa	Mutie MU0199	Kawelu sublocation	713 m, 1°49′49.8″ S, 38°12′23.0″ E
Launaea cornuta	Mutie MU0209	Kitoo sublocation	836 m, 1°54′46.1″ S, 38°11′00.9″ E
Sphaeranthus kirkii var. *cyathuloides*	Mutie MU0219	Kawelu sublocation	853 m, 1°51′03.3″ S, 38°09′57.8″ E
Tridax procumbens	Mutie MU0227	Mwala sublocation	868 m, 1°52′56.2″ S, 38°15′14.2″ E
Cucurbitaceae			
Kedrostis pseudogijef	Mutie MU0212	Kitoo sublocation, Ndiini village	836 m, 1°55′20.4″ S, 38°07′11.2″ E
Euphorbiaceae			
Croton dichogamus	Mutie MU0245	Kitoo sublocation, Ndiini village	836 m, 1°55″20.4′ S, 38°07″11.2′ E
Croton megalocarpus	Mutie MU0228	Mwala sublocation	868 m, 1°52′56.2″ S, 38°15′14.2″ E
Euphorbia crotonoides	Mutie MU0009	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Euphorbia scheffleri	Mutie MU0038	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Euphorbia uhligiana	Mutie MU0066	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Ricinus communis	Mutie MU0205	Kitoo sublocation	836 m, 1°54′46.1″ S, 38°11′00.9″ E
Lamiaceae			
Endostemon tereticaulis	Mutie MU0231	Kandae sublocation	868 m, 1°52′56.2″ S, 38°15′14.2″ E
Hoslundia opposita	Mutie MU0244	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Plectranthus lasianthus	Mutie MU0217	Kitoo sublocation, Ndiini village	836 m, 1°55′20.4″ S, 38°07′11.2″ E
Plectranthus otostegioides	Mutie MU0235	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Pycnostachys umbrosa	Mutie MU0213	Kitoo sublocation, Ndiini village	836 m, 1°55′20.4″ S, 38°07′11.2″ E
Volkameria eriophylla	Mutie MU0291	Mwala sublocation	868 m, 1°52′56.2″ S, 38°15′14.2″ E
Leguminosae			
Acacia brevispica	Mutie MU0031	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Acacia mellifera	Mutie MU0246	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Acacia nilotica	Mutie MU0224	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Acacia tortilis	Mutie MU0198	Kawelu sublocation	713 m, 1°49′49.8″ S, 38°12′23.0″ E
Albizia anthelmintica	Mutie MU0194	Kawelu sublocation	713 m, 1°49′49.8″ S, 38°12′23.0″ E
Cassia abbreviata	Mutie MU0221	Kawelu sublocation	853 m, 1°51′03.3″ S, 38°09′57.8″ E
Delonix elata	Mutie MU0233	Kibwea sublocation	868 m, 1°52′56.1″ S, 38°15′14.6″ E
Dichrostachys cinerea	Mutie MU0232	Kandae sublocation	868 m, 1°52′56.2″ S, 38°15′14.2″ E
Entada leptostachya	Mutie MU0229	Mwala sublocation	868 m, 1°52′56.2″ S, 38°15′14.2″ E
Indigofera lupatana	Mutie MU0053	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Senna occidentalis	Mutie MU0237	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Tamarindus indica	Mutie MU0208	Kitoo sublocation	836 m, 1°54′46.1″ S, 38°11′00.9″ E
Tephrosia villosa	Mutie MU0054	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E

Table 1: Continued.

Family and species name	Voucher number	Area of collection	Elevation and coordinates
Loganiaceae			
Strychnos henningsii	Mutie MU0200	Mwala sublocation	868 m, 1°52′56.2″ S, 38°15′14.2″ E
Malvaceae			
Grewia tembensis	Mutie MU0242	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Grewia tephrodermis	Mutie MU0220	Kawelu sublocation	853 m, 1°51′03.3″ S, 38°09′57.8″ E
Grewia villosa	Mutie MU0206	Kitoo sublocation	836 m, 1°54′46.1″ S, 38°11′00.9″ E
Sterculia africana	Mutie MU0211	Kitoo sublocation	836 m, 1°54′46.1″ S, 38°11′00.9″ E
Meliaceae			
Melia volkensii	Mutie MU0223	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Menispermaceae			
Chasmanthera dependens	Mutie MU0039	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Cissampelos pareira	Mutie MU0005	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Moraceae			
Ficus sycomorus	Mutie MU0202	Kibwea sublocation, Masaa river	676 m, 1°44′09.9″ S, 38°13′36.0″ E
Moringaceae			
Moringa borziana	Mutie MU0236	Kibwea sublocation	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Phyllanthaceae			
Bridelia taitensis	Mutie MU0239	Mutomo hill plant sanctuary	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Plumbaginaceae			
Plumbago zeylanica	Mutie MU0189	Kawelu sublocation, Ngomeni village	713 m, 1°49′49.8″ S, 38°12′23.0″ E
Rubiaceae			
Hymenodictyon parvifolium	Mutie MU0050	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Tennantia sennii	Mutie MU0027	Kitoo sublocation	836 m, 1°54′46.1″ S, 38°11′00.9″ E
Rutaceae			
Vepris simplicifolia	Mutie MU0234	Mutomo hill plant sanctuary	882 m, 1°52′56.1″ S, 38°15′14.6″ E
Zanthoxylum chalybeum	Mutie MU0317	Kandae sublocation	868 m, 1°52′56.2″ S, 38°15′14.2″ E
Solanaceae			
Solanum campylacanthum	Mutie MU0218	Kitoo sublocation, Ndiini village	836 m, 1°55′20.4″ S, 38°07′11.2″ E
Solanum tettense	Mutie MU0214	Kitoo sublocation, Ndiini village	836 m, 1°55′20.4″ S, 38°07′11.2″ E
Vitaceae			
Cissus aphyllantha	Mutie MU0247	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Cissus quadrangularis	Mutie MU0054	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Cissus rotundifolia	Mutie MU0128	Mutomo hill plant sanctuary	910 m, 1°49′49.8″ S, 38°12′23.0″ E
Xanthorrhoeaceae			
Aloe secundiflora	Mutie MU0191	Kawelu sublocation, Ngomeni village	713 m, 1°49′49.8″ S, 38°12′23.0″ E
Zygophyllaceae			
Balanites aegyptiaca	Mutie MU0210	Kitoo sublocation	836 m, 1°54′46.1″ S, 38°11′00.9″ E

names was further verified using The Plant List (http://www.theplantlist.org/).

The plant parts used for herbal medicines were classified according to Cook [62] while the plant growth habits were classified based on the monographs of Kenyan flora [59, 60]. The health conditions reported in the study area were classified according to Cook [62], where all the diseases reported by the informants belong to level one category of "*medicines*" while each disease cited by the informants belongs to a certain "*level two category*" within "*level one category*." Where the disorders could not be matched directly to level two categories, the body parts affected by the disorders were matched with their level two respective categories until all the ailments reported were categorized. The data were entered into an excel spreadsheet and analyzed to determine plant growth habit proportions, proportions of plant parts used, diseases treated, and the priority plant species based on Relative Frequency of Citation values (RFC). The RFC for each species was quantitatively calculated using the formula $\mathrm{RFC} = (\mathrm{FC}/N)\,(0 < \mathrm{RFC} < 1)$ [63], where the FC is the Frequency Citation, while N is the number of respondents participating in a particular study (here, $N = 48$). The RFC determines the consensus between the informants on the use of a reported plant species in a given area which in turn gives its local importance. The RFC values range from 0 to 1, where $\mathrm{RFC} = 0$ indicates that no informant mentioned the particular plant species while $\mathrm{RFC} = 1$ indicates that the plant species was cited by all informants in a particular study.

3. Results

3.1. Sociodemographic Data. A total of 48 local herbalists composed of 32 males and 16 females, aged between 32 and 96 years, with an average age of 68.25 years were interviewed. One herbalist was old (96 years) and collected the medicinal plants near his homestead. Two of the female herbalists sold the medicinal plants at Mutomo market, while all the other herbalists were farmers and served their customers or patients when consulted or visited. A majority (27%) of the herbalists were aged between 71 and 80 years and between 61 and 70 years (25%) while a number of them (18.75%) were over 80 years old. Only 2.08% of the herbalists were below 40 years old. In terms of education, majority of the herbalists (77.08%) had no formal education, 20.83% had at least attended primary school education although none of them had completed, while only 2.08% of the herbalists had completed secondary school training (Table 2).

Table 2: Demographic information of the herbalists.

Parameter	Percentage (%) composition
Demographic data	
Male	66.67
Female	33.33
Age group in years	
31–40	2.08
41–50	12.5
51–60	14.58
61–70	25
71–80	27
> 80	18.75
Level of education	
Secondary school education	2.08
Primary school education	20.83
No formal education	77.08

3.2. Medicinal Flora. Sixty-eight (68) plant species distributed in 28 families and 54 genera (Table 3) were reported to be used in the management of various human health conditions. Leguminosae comprised the majority of the species (13), followed by Euphorbiaceae and Lamiaceae, each with six species. A majority of the plant families comprised one species (Figure 2).

3.3. Growth Habit of the Medicinal Plants. Shrubs (37%) and trees (34%) were cited by the informants to be frequently collected for herbal medicine while herbs (18%), climbers (6%), and lianas (4%) were least cited (Figure 3).

3.4. Plant Parts Collected for Herbal Medicine. Roots and barks (each with 19 species) were reported to be the common plant parts collected for herbal medicine, followed by leaves (16 species), exudates (11 species), aerial parts (9 species), whole plants (4 species), fruits (4 species), stems (2 species) and inflorescence (1 species).

3.5. Frequently Collected Medicinal Plants. The RFC for each plant species was calculated. A summary of the RFC values of all medicinal plants reported from Mutomo hill plant sanctuary and its environs are outlined (Table 3). Plant species with five or more citations (RFC $\geq$ 0.10) were considered as the priority plant species. In total, 24 plant species were frequently cited by the respondents. *Cassia abbreviata* (RFC = 0.63), *Acacia nilotica* (RFC = 0.54), *Strychnos henningsii* (RFC = 0.46), and *Aloe secundiflora* (RFC = 0.31) had the highest RFC values (Figure 4).

3.6. Health Conditions Reported. In total, 13 disease categories including ethnoveterinary diseases were reported during the study. Infectious diseases and infestations were found to be treated with majority of the plant species (33) followed by digestive system disorders (24 plant species) (Table 4). These two disease categories are discussed in detail due to their perceived important role in the health of the people in the study area.

4. Discussion

4.1. Sociodemographic Data. All the herbalists who participated in the study were over 30 years old, mostly dwelling in the rural areas. People living in the rural areas are reported to acquire more ethnobotanical knowledge probably due to the availability of plants in their surroundings [75]. A large percentage of the herbalists had no formal education, a proportion that was below the national average level of adult literacy in Kenya [76]. The low level of formal education in herbal practitioners has also been reported in other regions of Kenya [67, 77]. This contradicts a previous study in Kitui county where most of the respondents had acquired formal education up to primary school level [34]. According to a report by the county government of Kitui, people over 65 years old are considered aged and not economically productive [54]. In this study, however, the aged people were found to be actively practicing traditional medicine which in some instances was a source of income since some of them sold the herbal products in the market. Elderly people practicing traditional medicine has been reported elsewhere in Kenya [77]. It is also argued that the level of ethnobotanical knowledge may increase as people advance in age probably due to increased responsibilities [75] which partly explains the high number of aged herbalists. Generally, the population of females is higher than that of males in Kitui county [54], yet most of the herbalists in the study were males. This agrees with Kaingu et al. [77] who reported males to comprise most of the herbalists in a previous study, although this is contradicted by a recent study in Kitui county [34] where women were reported to comprise most of the respondents. Despite such variations, there may be no difference in the level of ethnobotanical knowledge between the two genders [75].

Most of the herbalists preferred collecting medicinal plants on their own, which in some cases involved travelling for hours, unless a plant species could be found in their vicinity or was an obvious tree, where they could ask for assistance. The herbalists who stored herbal materials for future use also kept it a secret and normally stored them mixed together or ground into a powder to make utilization or identification by an unfamiliar person difficult. In addition, most of the herbalists chose to be interviewed in the absence of other people including some of their family members except their spouses and one or two confidants. This is likely to contribute to the degradation of traditional knowledge in young generations since the chances of acquiring it are controlled by those who possess it. Although Kisangau et al. [34] found that most of the respondents had acquired traditional knowledge through apprenticeship from family members, Muthee et al. [67] argues that the poor traditional knowledge in young generations could be an

Table 3: An account of the medicinal plants reported in Mutomo hill plant sanctuary and its environs. The relevant reported medicinal uses of the plant species or literature reporting other medicinal applications of the plant species have been indicated where possible.

Family and species name	Local name	Habit	RFC	Parts collected	Drug preparation and administration	Disease treated	Relevant reported disease treated or use
Acanthaceae							
Barleria eranthemoides R.Br. Ex C.B.Clarke	Thangila	Shrub	0.06	Leaf, root	A poultice is applied topically	Foreign objects pierced into the skin and boils	References [13, 64]
Amaranthaceae							
Achyranthes aspera var. *sicula L.*	Musekele	Herb	0.02	Whole plant	Burnt to charcoal and ground into a powder which is taken in hot drinks. The powder is alternatively rubbed on a bleeding part of the body that is cut with a razor adjacent to the kidney	Kidney pains	Urinary tract problems [41]
Anacardiaceae							
Lannea schweinfurthii Engl.	Kyuasi	Tree	0.02	Bark	An infusion is drunk	Gonorrhea	Gonorrhea, venereal diseases, and gynecological problems [1, 44, 64]
Apiaceae							
Steganotaenia araliacea Hochst.	Kivwavui	Tree	0.04	Exudate, aerial parts	An exudate is dropped into the eyes in case of sensitiveness or itching. An infusion from aerial parts is steam bathed for edema	Itching eyes, sensitive eyes, edema	Edema, partial blindness, and body swellings resulting from allergy [1, 41, 64]
Apocynaceae							
Calotropis procera (Aiton) Dryand.	Ilumbu	Shrub	0.04	Exudate	Applied topically	Foreign objects pierced into the body	Removing splinters pierced into the body [64]
Edithcolea grandis N.E.Br.	Mutulya-ndu	Herb	0.02	Exudate	Applied topically on infected skin	Ringworms	Reference [64]
Asparagaceae							
Sansevieria perrotti Warb.	Kiwa kya ndui	Herb	0.02	Exudate	The leaf is heated in hot ash and the exudate squeezed into the ear. The treatment is initiated when the ear starts to ooze pus	Earache	Cuts and body aches [1, 65]
Burseraceae							
Commiphora baluensis Engl.	Itula	Tree	0.15	Bark	An infusion is drunk. Alternatively, the bark is dried and ground into a powder which is infused in hot drinks	Diarrhea, swollen diaphragm	Peptic ulcers [64]
Commiphora edulis (Klotzsch) Engl.	Kyoa kika	Tree	0.04	Bark	An infusion is drunk	Tapeworms, cough, chest pains	Diarrhea, dysentery, and indigestion [1, 44]
Commiphora habessinica (O.Berg) Engl.	Mutungati	Tree	0.06	Exudate	Applied topically	Septic wounds	Old wounds [64]
Capparaceae							
Boscia coriacea Graells	Musivu	Shrub	0.06	Leaf	An infusion is drunk	Diarrhea	Stomach-ache [1, 29, 66]

Table 3: Continued.

Family and species name	Local name	Habit	RFC	Parts collected	Drug preparation and administration	Disease treated	Relevant reported disease treated or use
Maerua endlichii Gilg and Bened.	Muthitu	Shrub	0.02	Stem	Burnt into charcoal, ground into a powder, and infused in hot drinks	Swollen diaphragm	Reference [29]
Combretaceae							
Combretum hereroense Schinz	Mukokola	Shrub	0.06	Leaf	Chewed and the extract swallowed	Tuberculosis, cough	Chest pains [44]
Terminalia brownii Fresen.	Kiuku	Tree	0.29	Bark	Bark from the stems or roots is chewed and the extracts swallowed for cough. A warm infusion is bathed for yellow fever and drunk against diarrhea	Cough, yellow fever, and diarrhea	Yellow fever, jaundice, stomach-ache, gastrointestinal complications, and cough [1, 29, 34, 36, 66]
Terminalia prunioides M.A.Lawson	Kitoo	Tree	0.02	Bark	A decoction is drunk	Ringworms, peptic ulcers, kidney pains, and aphrodisiac in men	Reference [60]
Compositae							
Aspilia pluriseta Schweinf. ex Schweinf.	Muti	Shrub	0.02	Leaf	A poultice is applied topically	Fresh cuts	Wounds and cuts [1, 34, 64, 66]
Kleinia squarrosa Cufod.	Mung'endya Nthenge	Herb	0.13	Aerial parts	An infusion is bathed	Malaria, measles, smallpox, and edema	Malaria and edema [13, 34, 64]
Launaea cornuta (Hochst. ex Oliv. and Hiern) C.Jeffrey	Uthunga	Herb	0.08	Aerial parts	An infusion is bathed	Malaria, smallpox, edema	Malaria, arthritis, and measles [1, 34, 64]
Sphaeranthus kirkii var. *cyathuloides* (O.Hoffm.) Beentje	Musonzoila	Herb	0.10	Aerial parts	An infusion is bathed	Malaria, edema	Headache [1]
Tridax procumbens (L.) *L.*	Mumela	Herb	0.04	Leaf	A poultice is applied topically	Fresh cuts, wounds	Wounds [64]
Cucurbitaceae							
Kedrostis pseudogijef C. Jeffrey	Mukauw'u	Climber	0.04	Leaf, exudate	A leaf infusion is bathed against measles. An exudate applied on fresh cuts	Measles, fresh cuts	Reference [64]
Euphorbiaceae							
Croton dichogamus Pax	Mwalula	Herb	0.13	Bark, leaf	An infusion from the bark is drunk for malaria, back pains, stomach-ache, edema, and cough. An infusion from the leaves is bathed for malaria. A root decoction is drunk for impotence and infertility	Malaria, back pains, stomach-ache, edema, cough, impotence, and infertility	Stomach-ache, chest problems, fever, cough, and as a tonic [1, 60, 66]

Table 3: Continued.

Family and species name	Local name	Habit	RFC	Parts collected	Drug preparation and administration	Disease treated	Relevant reported disease treated or use
Croton megalocarpus Hutch.	Muthulu	Tree	0.19	Bark, leaf	An infusion from the bark is drunk for constipation and stomach-ache. The bark is alternatively dried and ground into a powder which is infused in hot drinks. A warm leaf infusion is bathed against malaria and colds	Constipation, stomach-ache, malaria, colds	Stomach-ache, diarrhea, and malaria [1, 36, 64]
Euphorbia crotonoides Boiss.	Kamweia	Herb	0.02	Exudate	Applied topically	Warts	Warts [1]
Euphorbia scheffleri Pax	Kilembwa	Shrub	0.04	Exudate	Applied topically	Fresh cuts	References [1, 13]
Euphorbia uhligiana Pax	Kyaa kinini	Herb	0.02	Whole plant	Burnt to charcoal and ground into a powder which is infused in hot drinks	Hypertension	References [1, 65]
Ricinus communis L.	Mbaiki	Herb	0.04	Roots, seeds	An infusion from the root is drunk against diarrhea. The anal opening is exposed to smoke from burning seeds as a remedy for pinworms	Diarrhea, pinworms	Diarrhea and stomach-ache, ruminal impaction or constipation and as a laxative [1, 34, 41, 64, 66, 67]
Lamiaceae							
Endostemon tereticaulis (Poir.) M.R.Ashby	Mutaa	Herb	0.10	Aerial parts, roots	An infusion from aerial parts is bathed and drunk against malaria, edema, and diarrhea. Powder from dried roots is infused in hot drinks as a remedy against back pains	Malaria, edema and diarrhea, back pains	Reference [1]
Hoslundia opposita Vahl	Musovi	Shrub	0.02	Leaf	An infusion is steam bathed	Edema	Edema [64]
Plectranthus lasianthus (Gürke) Vollesen	Kiyo	Herb	0.02	Whole plant	An infusion is steam bathed	Kwashiorkor, edema in children	Reference [68]
Plectranthus otostegioides (Gürke) Ryding	Kyeu	Shrub	0.02	Whole plant	An infusion is steam bathed	Kwashiorkor, edema in children	Reference [69]
Pycnostachys umbrosa (Vatke) Perkins	Muvou	Shrub	0.02	Root	An infusion is drunk	Diarrhea, stomach-ache	Emetic [60]
Volkameria eriophylla (Gürke) Mabb. and Y.W.Yuan	Muumba	Shrub	0.15	Leaf	An infusion is drunk and steam bathed against malaria and edema	Malaria, edema	Edema and malaria [1, 64]
Leguminosae							
Acacia brevispica Harms	Mukuswi	Shrub	0.02	Aerial parts	An infusion is steam bathed	Edema	Edema [64]
Acacia mellifera (M.Vahl) Benth.	Kithiia	Shrub	0.02	Bark	An infusion is drunk, sometimes mixed with the bark of *Lannea schweinfurthii*	Gonorrhea	References [1, 66]

Table 3: Continued.

Family and species name	Local name	Habit	RFC	Parts collected	Drug preparation and administration	Disease treated	Relevant reported disease treated or use
Acacia nilotica (L.) Delile	Kisemei	Tree	0.54	Bark	Chewed and extracts swallowed. An infusion is alternatively drunk	Cough, chest pains, malaria, pneumonia	Malaria, cough, chest pains, and pneumonia [1, 34, 42, 44, 64, 66]
Acacia tortilis (Forssk.) Hayne	Mwaa	Tree	0.25	Bark, root	Fresh root is dried in hot ash and smoked like a cigarette as a remedy for flu. The bark is chewed against cough and pneumonia. Alternatively, an infusion from the bark is drunk	Flu, cough, and pneumonia	Cough and colds [29, 64]
Albizia anthelmintica Brongn.	Kyoa kisamba	Tree	0.25	Bark	An infusion is steam bathed against edema and drunk against tapeworm, gonorrhea, and measles. The bark is burnt into charcoal and ground into a powder which is applied on septic wounds	Edema, tapeworm, gonorrhea, measles, and wounds	Intestinal worms, edema, old wounds, and gonorrhea [1, 32, 34, 64, 66, 67, 70]
Cassia abbreviata Oliv.	Kyalandathe	Tree	0.63	Aerial parts, bark	Aerial parts are chewed and the juice retained in the mouth as a remedy for toothache. A decoction or an infusion from the stem or bark is drunk against cough, malaria, gonorrhea, kidney pains, colds, and pain in joints	Toothache, cough, malaria, gonorrhea, kidney pains, colds, and pain in joints	Gonorrhea, malaria, pneumonia and chest complaints [1, 66]
Delonix elata (L.) Gamble	Mwaange	Tree	0.02	Bark	Dried and ground into a powder and topically applied	Septic wounds	Wounds [64].
Dichrostachys cinerea (L.) Wight and Arn.	Munoa-mathoka	Shrub	0.02	Bark	Chewed and the extracts swallowed	Cough	Cough [64]
Entada leptostachya Harms	Mwaitha	Climber	0.10	Exudate, root	The exudate is applied into an injured eye. A root infusion is taken in case of food poisoning or a snake bite. A root poultice is used to message the body in case of an internal injury	Eye injury, food poisoning, snake bite, and internal injury	Snake bites, cuts, arrow poisoning and eye injuries [29, 34, 64]
Indigofera lupatana Baker f.	Muthika	Shrub	0.10	Bark	An infusion from the root bark is drunk for cough, diarrhea, and constipation. The root bark is alternatively chewed and the extracts swallowed	Cough, diarrhea, and constipation	Cough and stomach-ache [29, 34, 64]
Senna occidentalis (L.) Link	Musingili	Herb	0.04	Root	An infusion is drunk	Stomach-ache and diarrhea	Stomach-ache and diarrhea [1, 15]

Table 3: Continued.

Family and species name	Local name	Habit	RFC	Parts collected	Drug preparation and administration	Disease treated	Relevant reported disease treated or use
Tamarindus indica L.	Kithumula	Tree	0.19	Leaf, fruit	An infusion from the fruit is drunk against tonsillitis. The tonsils are also massaged with leaf and fruit poultice. An infusion of fruits and leaves is drunk and bathed against smallpox, measles, and edema	Tonsillitis, smallpox, measles, and edema	Coughs, throat, measles, chicken pox, edema, sore throat, and oral thrush [1, 64]
Tephrosia villosa (L.) Pers.	Mwenyu	Herb	0.02	Root	A decoction is drunk	Malaria	Fever [44]
Loganiaceae							
Strychnos henningsii Gilg	Muteta	Tree	0.46	Bark, leaf	An infusion is drunk or powder from dried leaves and bark is infused in hot drinks	Malaria, constipation, pneumonia, kidney pains	Body pains, malaria, pneumonia, chest pains, and stomach-ache [1, 32, 34, 64]
Malvaceae							
Grewia tembensis Fresen.	Mutuva	Shrub	0.04	Bark	A decoction is drunk or the roots dried, ground into a powder, and infused in hot drinks	Reduced appetite, swollen diaphragm	Heartburn and cough [64, 65]
Grewia tephrodermis K.Schum.	Mulawa	Shrub	0.06	Roots, aerial parts	A root decoction is drunk against diarrhea, stomach-ache, and as an aphrodisiac in men. An infusion from the aerial parts is steam bathed for edema and skin rashes	Diarrhea, stomach-ache, aphrodisiac in men, edema, skin rashes	Dermatitis, diarrhea and restoring female fertility [1, 29, 64]
Grewia villosa Willd.	Muvu	Shrub	0.06	Root	An infusion is drunk	Diarrhea	Diarrhea, stomach-ache, and amoeboid dysentery [1, 64, 66]
Sterculia africana (Lour.) Fiori	Kiusya		0.13	Bark, aerial parts	An infusion is drunk	Diarrhea	Diarrhea and dysentery [1]
Meliaceae							
Melia volkensii Gürke	Mukau	Tree	0.04	Leaf	A decoction is drunk and bathed	Malaria, edema	Edema and malaria [34, 64]
Menispermaceae							
Chasmanthera dependens Hochst.	Usyiii	Liana	0.04	Stem	An infusion is drunk	Diarrhea	Reference [60]
Cissampelos pareira L.	Kutu kumwe	Climber	0.15	Root	An infusion is drunk	Diarrhea, stomach-ache	Stomach ailments [1, 44]
Moraceae							
Ficus sycomorus L.	Mukuyu	Tree	0.02	Exudate	Applied on tooth	Toothache	Toothache [1, 44]
Moringaceae							
Moringa borziana Mattei	Mululo	Shrub	0.17	Root	An infusion is bathed against edema and drunk for malaria and gonorrhea. The roots are alternatively dried and ground into a powder which is infused in hot drinks	Edema, malaria, and gonorrhea	References [71, 72]
Phyllanthaceae							

Table 3: Continued.

Family and species name	Local name	Habit	RFC	Parts collected	Drug preparation and administration	Disease treated	Relevant reported disease treated or use
Bridelia taitensis Vatke and Pax ex Pax	Kyaanthya	Tree	0.02	Leaf	Is used as a bandage after application of herbal medicine in the form of a powder	Septic wounds	Reference [1]
Plumbaginaceae							
Plumbago zeylanica L.	Wala	Shrub	0.10	Root	A decoction is drunk, sometimes mixed with roots of *Moringa borziana*	Gonorrhea	Gonorrhea [64]
Rubiaceae							
Hymenodictyon parvifolium Oliv.	Mulinditi	Shrub	0.02	Root	An infusion is steam bathed	Edema	Edema [64]
Tennantia sennii (Chiov.) Verdc. and Bridson	Kisilingu	Shrub	0.08	Root	A decoction is drunk	Diarrhea, malaria, impotence, and infertility	Literature not found
Rutaceae							
Vepris simplicifolia (Engl.) Mziray	Mutuyu	Tree	0.10	Leaf, bark, root	An infusion is drunk and steam bathed	Edema, malaria	General body pains, malaria, and pleurisy [1, 17, 34, 36, 64, 66]
Zanthoxylum chalybeum Engl.	Mukenea	Tree	0.27	Bark, fruit	The root bark poultice is applied on an aching tooth as a remedy for toothache. An infusion from the bark or fruit is drunk against malaria, edema and cough. Alternatively, the bark, and the fruit are ground into a powder which is infused in hot drinks	Toothache, malaria, edema, and cough	Malaria, edema, cough, and toothache [1, 17, 29, 34, 64, 66]
Solanaceae							
Solanum campylacanthum Hochst.	Kitongu	Shrub	0.15	Root, fruit	An infusion from the root is drunk against diarrhea. Juice from a fruit is retained in the mouth as a remedy for toothache. Juice from a ripe fruit is applied topically on body parts infected with ringworms	Diarrhea, toothache, and ringworms	Stomach-ache, diarrhea, amoeboid dysentery, toothache, and ringworms [1, 32–34, 41, 64, 66, 73]
Solanum tettense Klotzsch	Mutongatongu	Shrub	0.02	Root	A decoction is drunk	Diarrhea and stomach-ache	Stomach-ache [64]
Vitaceae							
Cissus aphyllantha Gilg	Muvelengwa	Liana	0.06	Root	An infusion is used as a head wash in case of headache and drunk against diarrhea and pneumonia	Headache, diarrhea, and pneumonia	Diarrhea and amoeboid dysentery [34, 64]
Cissus rotundifolia Vahl	Itulu	Liana	0.02	Leaf	A poultice is used as a bandage	Septic wounds	Septic body swellings, boils, and used as ear drops [32, 44]
Xanthorrhoeaceae							

Table 3: Continued.

Family and species name	Local name	Habit	RFC	Parts collected	Drug preparation and administration	Disease treated	Relevant reported disease treated or use
Aloe secundiflora Engl.		Herb	0.31	Exudate, inflorescence	An infusion of the exudate is drunk against malaria, cough, peptic ulcers, and a swelling of the diaphragm. The peduncle of the inflorescence is alternatively burnt to charcoal and ground into a powder which is licked or infused in hot drinks. An exudate from the leaf is dropped on septic wounds	Malaria, cough, peptic ulcers, swelling of the diaphragm, and wounds	Malaria, diarrhea, ulcers, swollen diaphragm, open wounds, and lack of appetite [1, 29, 34, 38, 64, 67, 73]
Zygophyllaceae *Balanites aegyptiaca* (L.) Delile	Kilului	Tree	0.08	Fruit	The pulp of a ripe fruit is eaten	Colds, cough, and kwashiorkor	Kwashiorkor, cough, and chest complaints [1, 29, 66]

indication that it is not being transferred or is acquired after a long period of time. This is further supported by Nanyingi et al. [36] who found that the knowledge on the treatment of some diseases was possessed by the elder members of the society. There are reports that in some regions of Kenya, the young generations are ignorant of traditional practices after taking up formal education [37, 45]. However, external factors such as education may not negatively affect the sustainability of traditional knowledge in people who have already acquired it [75]. It is likely that there exists a barrier limiting the transfer of traditional knowledge between the old and the young generations, a complexity that needs elaboration in future studies.

4.2. Medicinal Flora. Leguminosae was the dominant plant family reported during the study followed by Euphorbiaceae and Lamiaceae. Leguminosae was also reported to be among the frequently used plant families in treatment of malaria in Kwale community [78] and in the management of HIV/AIDS in Mfangano Island in Kenya [15]. In the study of medicinal plants used by the Marakwet community, Mimosaceae was the dominant plant family reported [79] while in the study of medicinal plants of Tana river county, Euphorbiaceae, Leguminosae, and Lamiaceae were found to be among the frequently used plant families [30, 77]. In the flora of Kitui county, Leguminosae is the largest plant family [46]. It is also the largest plant family in the flora of Kenya [24]. African legumes are tolerant to drought and therefore comprise important resources for people living in arid areas [80]. Considering the amount of rainfall received in drylands of Kenya [81] and its elevational range [25], Kitui county can be considered as a typical dryland region; hence the large number of legumes could be attributed to the arid conditions of the area.

Shrubs and trees were the dominant life forms reported, which agrees with the results of another study in Kenya [36]. An ethnobotanical study among the Marakwet community in Kenya reported trees to be the frequently used plant life forms [79] while among the Kwale people of Kenya, shrubs were found to be frequently utilized for the treatment of malaria [78]. In mount Elgon, a study of medicinal plants reported that trees were the dominant life forms used followed by shrubs [41]. Generally, the vegetation of the study area is dominated mostly by dry forests composed of shrubs [46, 56, 64]. Shrubs can also be obtained from many areas including bushlands and farmlands [44], making it easier for the local communities to access them.

In this study, roots and barks were found to be frequently collected for herbal medicine. A single plant species may have several parts collected for herbal medicine [82] which was also reported during the study. Some plant species were reported to be used as whole plants. The use of the whole plants in Kenya is reported to be applied in cases of small plants, herbaceous plants, or epiphytes [44]. In a similarly arid region in Kenya, roots and barks were found to be frequently collected for herbal medicine [45]. In a study of medicinal plants used by the Sabaot people of mount Elgon, roots were found to be frequently utilized followed by the barks and leaves [41]. Moreover, in a survey of medicinal plants in the urban areas of Kenya, roots and barks were found to be the common plant parts sold [21]. In some studies, leaves are reported to be frequently collected with significant proportions of barks and roots being reported [34, 82, 83]. According to Malonza et al. [46], debarking and uprooting are some of the common techniques of harvesting medicinal plants used by the people of Kitui. Harvesting of root and bark increases the level of vulnerability of plants since the two parts take a longer time to regenerate when compared to the leaves; hence the chances of survival of debarked trees are rare [34, 47]. Debarked plants are likely to be in danger of overexploitation; hence their conservation

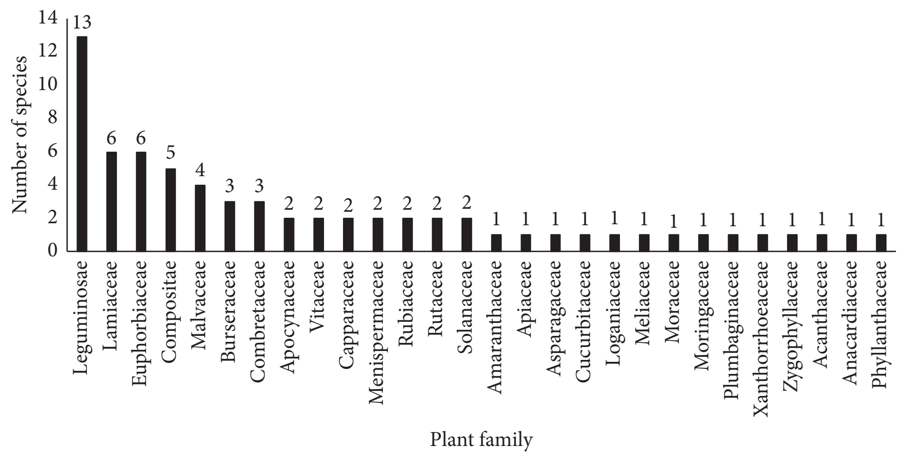

Figure 2: Distribution of plant species in different families.

status needs further investigation [82]. Since plants found in dry areas are perceived to be of better medicinal quality, they are preferred for collection by traders and herbalists, thus risking degradation due to their high demand [84]. In the semiarid areas of Kenya, the effects of overutilization, desertification, and global warming have subjected biodiversity to increased pressure [45]. A combination of such factors with the vulnerable nature of semiarid lands may lead to further reduction of habitats which harbor medicinal plants [67]. Therefore, substituting the roots and barks with plant parts such as leaves and aerial parts may reduce the pressure exerted on medicinal plants [47]. In addition, bioactive compounds from plants are mostly extracted using water [41, 45] whose efficacy may be low compared to other media such as methanol, suggesting that ineffective media for extracting plant-based compounds may lead to wastage of the harvested materials; hence traditional healers need to be trained on other potential effective methods [45]. Conservation initiatives of the plant species endangered by overexploitation are therefore necessary [46] and Mutomo hill plant sanctuary is potentially a suitable area for such initiatives in Kitui county.

There were 24 plant species frequently collected by the herbalists in the study area, all of which can be treated as priority plants based on Njoroge et al. [40]. From this study, five plant species (*Zanthoxylum chalybeum, Terminalia brownii, Croton megalocarpus*, *Albizia anthelmintica,* and *Aloe secundiflora*) have been reported as priority medicinal plants elsewhere in Kitui county [40]. *Zanthoxylum* and *Strychnos* species are also among the most preferred plant species for herbal medicine in Kitui county [46]. *Acacia nilotica* and *Strychnos henningsii* were also found to be among the most popular plant species used in the management of respiratory infections at Kibwezi, an area adjacent to Mutomo subcounty [45]. As reported in a previous study [41], most of the plant species were obtained from the wild. In this study, all the *Commiphora* species were found to be cultivated by some informants as hedge plants especially along fences. This is because *Commiphora* species can be propagated easily from cuttings since they root easily once driven into the ground [60]. Cultivation of plants as live fences has been undertaken by some local communities in Kenya as a way of preserving scarce medicinal plants [36]. Other plant species cultivated were *Aloe secundiflora*, *Croton megalocarpus,* and *Melia volkensii*. The herbalists reported an increasing scarcity of *Strychnos henningsii* and *Vepris simplicifolia*, relating it to land conversion for farmlands and private development. The decline of *Strychnos henningsii* in the wild was previously reported in Kitui county [40]. Due to the increasing scarcity of medicinal plants, some herbalists reported retaining *Terminalia brownii, Tamarindus indica*, *Balanites aegyptiaca,* and *Moringa borziana* in their farmlands for future medicinal uses. Njoroge et al. [40] also reported that *Terminalia brownii*, *Croton megalocarpus,* and *Aloe secundiflora* were preserved in the farmlands for future medicinal uses. The abundance of useful plants has been reported to decline as a result of fluctuating rainfall patterns and anthropogenic activities such as selective harvesting, overexploitation, and expansion of farmlands [85]. In Kitui county, *Acacia tortilis* and *Terminalia brownii* are also reported to be used for charcoal [34] which may further reduce their abundance in the wild. Some medicinal plants found in this study such as *Zanthoxylum chalybeum* and *Albizia anthelmintica* are also sold in the urban areas of Kenya [21]. During the study, *Cassia abbreviata*, *Terminalia brownii,* and *Vepris simplicifolia* were found to be sold in Mutomo market. Several important collection sites for medicinal plants in Kenya are reported to have been converted into farmlands [86]. In an ethnobotanical study in Zanzibar, the abundance of some medicinal plants is reported to have decreased making it difficult to obtain them from the wild [87]. The supply of medicinal plant products sold in the Kenyan urban centers is also decreasing [21]. Amir et al. [88] reported that few people in Tanzania cultivated medicinal *Aloe* species and that most of them were being obtained from the wild, resulting in the decline of wild *Aloe* populations. *Aloe* species in Kenya, are however threatened by factors related to the increase in human and livestock populations and international trade rather than utilization for herbal medicinal [89]. Generally, medicinal plants in Kenya are threatened by both natural and anthropogenic factors where the majority of them have declined due to deforestation [36].

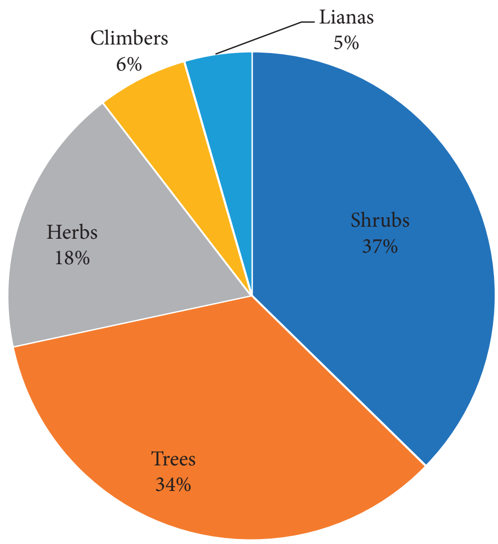

Figure 3: Distribution of plant growth habits.

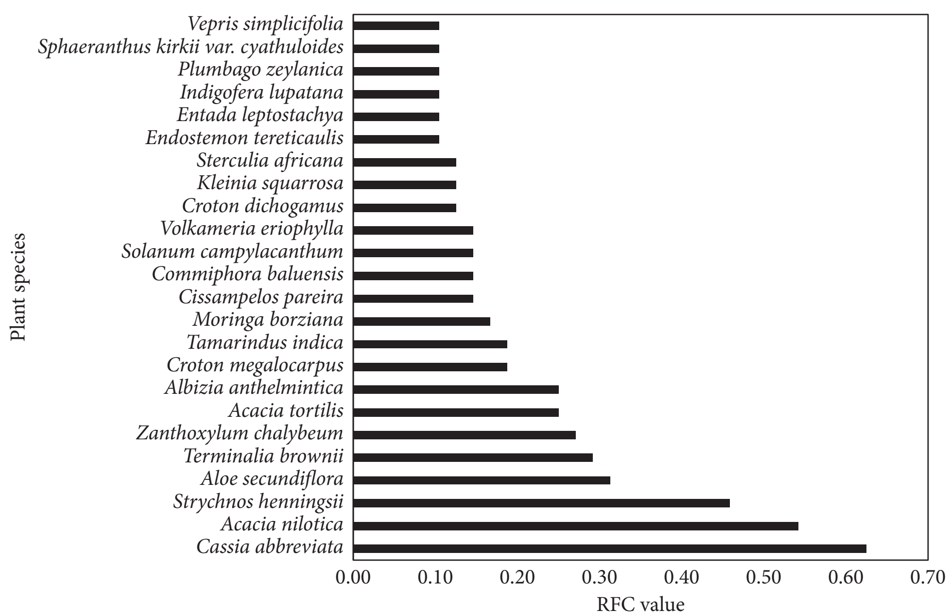

Figure 4: Frequently used plant species.

4.3. Medicinal Uses. The medicinal applications of most of the plant species reported in this study have been reported before although the diseases treated, the parts used, the methods of preparation, and administration of the drugs may differ in some instances. A previous study reported on novel therapeutic applications of some plant species in Kenya [41]. However, further botanical investigations of voucher collections stored in various herbaria are necessary before conclusions can be arrived at. Plant species belonging to the same genus may be used for the management of similar health conditions. Such species may have the same local names such as those of genus *Sphaeranthus*, which are reported to be used in the treatment of malaria and edema [64]. Morgan [65] also found out that the same local names were being applied by the local community to refer to *Indigofera* and *Crotalaria* species. During the field survey, an herbalist mentioned that *Indigofera arrecta* and *I. lupatana* could at times be confused since the two plants share the same local name in the study area. Substituting *I. arrecta* with *I. lupatana* was sometimes applicable although the latter was reported to be more effective. Phytochemical investigations to determine the effectiveness of the two species in the management of the said ailments are therefore in need. Some cases of health management involved the treatment of symptoms of the reported ailments. For example, reduced appetite was reported to be a symptom of a swollen diaphragm; hence the two conditions were managed simultaneously. Some cases of herbal preparations involved mixing of different plant species, which the herbalists claimed was a remedy for notorious diseases or a suspected

Table 4: Classifications of diseases reported in Mutomo hill plant sanctuary and its environs.

Disease categories	Disorders reported	Number of plant taxa used
Infections or infestations	Gonorrhea, ringworms, tapeworms, pinworms, tuberculosis, yellow fever, malaria, measles, small pox, colds, pneumonia, and flu	33
Digestive system disorders	Diarrhea, peptic ulcers, stomach-ache, constipation, and toothache	24
Body abnormalities	Edema "body swelling"	19
Respiratory system disorders	Swollen diaphragm, cough, chest pains, tonsillitis, and swelling of the diaphragm	15
Body injuries	Boils, foreign objects pierced into the body, septic wounds, fresh cuts, and internal injuries	13
Genitourinary system disorders	Kidney pains, aphrodisiacs, impotence, and infertility	7
Muscular-skeletal system disorders	Back pains, pain in joints, and headache	4
Nutritional disorders	Kwashiorkor, reduced appetite	4
Sensory system disorders	Eye problems, earache	3
Skin/subcutaneous cellular tissue disorders	Warts, skin rashes	2
Circulatory system disorders	Hypertension	1
Poisonings	Snake bites, food poisoning	1
Ethnoveterinary applications	Diarrhea in livestock, tick infestation, eye problems, liver diseases, lung diseases	12

combination of two diseases. Mixing of medicinal plants for the treatment of a single ailment has been reported in other studies [32, 36]. In addition, some herbal products sold in Kenyan urban areas for the treatment of some diseases are prepared mixed [21]. Since the efficacies of most plant species used in traditional medicine have not been tested, their role in disease management cannot be ascertained [45]. Ethnobotanical studies in Kenya are also considered few in light of the high plant diversity in the country [36]. Although literature reveals that an enormous data on medicinal plants of Kenya exist [1], ethnomedicinal applications of some plant species have not been documented to date. As a result, Njoroge et al. [40] emphasized the need for the documentation of ethnomedicinal uses of regional floras.

Infections and digestive system disorders are treated with most of the medicinal plant species in some parts of Kenya [32, 34]. Tuberculosis was reported to be managed by chewing the leaves of *Combretum hereroense* and swallowing the extract. Tuberculosis is a bacterial disease majorly affecting the lungs although it has been reported to advance to the ears and the tonsils especially in Africa [90–92]. Earache and tonsillitis were also reported to be managed using herbal medicines. However, based on this ethnobotanical survey, the relationship between tuberculosis and such ailments cannot be ascertained. *Acacia nilotica*, *A. tortilis*, *Strychnos henningsii,* and *Cissus aphyllantha* were reported to be used for the treatment of pneumonia. *Acacia nilotica* and *Strychnos henningsii* have been found to show efficacy against the pathogens causing respiratory infections including pneumonia [45]. Pneumonia is reportedly the leading disease in childhood mortality, especially in marginalized communities of developing countries [93]. In recent years, respiratory infections have become resistant to antibiotics, resulting in ineffectiveness in their treatment which has led to advocacy in search of plant-based antimicrobial drugs [45, 82, 94]. Decoctions of *Lannea schweinfurthii* and *Plumbago zeylanica* were reported for the treatment of gonorrhea. A similar application of *Lannea schweinfurthii* has been reported before [64]. One herbalist admitted to advising his family members to take a decoction of *Lannea schweinfurthii* against gonorrhea at least once a month to avoid the chances of contracting the disease. It is likely that the local herbalists are aware of the adverse effects associated with the disease especially in women in spite of its asymptomatic nature [95]. Gonorrhea pathogen is reported to show resistance to clinical therapies [96]; hence medicinal plants may offer other opportunities for the development of novel drugs against such infections.

Some herbalists reported that pain in joints, general body pains, and headache were symptoms of malaria. These conditions together with malaria were therefore managed by the herbalists using the same medicinal plants. Although such ailments are categorized under muscular-skeletal disorders, their association with malaria has been reported in other studies in Kenya [97, 98]. *Cassia abbreviata* and *Albizia anthelmintica* which were reported for the treatment of malaria have been reported to have no or a weak antiplasmodial activity; hence they are likely to be applied in the treatment of conditions that accompany malaria [99]. Plant species such as *Strychnos henningsii*, *Aloe secundiflora*, and *Zanthoxylum chalybeum* which have been reported for the treatment of chronic joint pains [100] were reported for treatment of malaria during the study. A bath from an infusion of *Kleinia squarrosa* was also reported to be used against malaria. Chemical analysis of *Kleinia squarrosa* has revealed that essential oils from the plant contain volatile compounds that act as mosquito repellants [101] which further supports its application in the management of mosquito-related ailments. Malaria was reported to be treated through the administration of decoctions, infusions, and bathes. Historical treatments of malaria with plant-based derivatives are the use of quinine and artemisinin as antimalarial drugs [97]. Treatment of malaria with medicinal plants is also widely reported in Kenya [17, 98]. Some medicinal plants which were reported for treatment of malaria such as *Vepris simplicifolia* and *Zanthoxylum chalybeum* have proven antiplasmodial activities [99]. Malaria is a major hindrance to economic growth in Sub-Saharan Africa [102] and it is also among the leading diseases in childhood mortality and in deaths of pregnant mothers in Africa [93]. In recent years, it has become difficult to treat malaria owing to the development of plasmodial resistance against the available clinical drugs [103]. The high prevalence of malaria infection in rural areas of Kenya has led the local communities to rely on medicinal plants, with some rural inhabitants reporting them to be more effective and cheaper compared to clinical therapies [98].

Viral infections reported during the study to be managed using medicinal plants included yellow fever, measles, smallpox, colds, and flu. Common colds are caused by numerous viruses belonging to different families and they display varying clinical manifestations. Influenzas, the viruses causing flu are among the viruses associated with common colds. A universal mode of treatment and prevention of the disorders arising from common colds has not been developed due to the varying pathogenic mechanisms of the viruses [104]. Yellow fever was reported to be treated through bathing an infusion of *Terminalia brownii*, as previously reported [34, 60]. Yellow fever is a disease in tropical South America and Africa with no specific treatment and is currently managed using vaccines [105, 106]. *Tamarindus indica* was reported for the treatment of measles and smallpox by consumption of the fruits, steam bathing, or by taking an infusion from the fruit and leaves, as reported elsewhere [64]. In addition, a bath from an infusion of *Kleinia squarrosa* was also reported to treat smallpox and measles. According to two herbalists, cases of smallpox outbreak are nowadays rare. Vaccinations have effectively dealt with smallpox and are on the verge of eliminating measles, while the vaccine against yellow fever virus induces a long-term immunity once administered [107]. Other than vaccination, measles is prevented through supplementation of vitamin A [108, 109]. However, Sub-Saharan Africa is classified by the WHO as a region with the highest rates of vitamin A deficiency [109]. Although control of some viral infections through vaccination has been effective, viruses still develop resistance to drugs making the treatment of associated diseases extremely difficult [110]. Hence the role of medicinal plants in the treatment of viral diseases cannot be neglected.

Taenia worms were reported to be primarily expelled using a decoction of *Albizia anthelmintica*, an application that has been quoted in various studies [1, 34, 60, 64]. The plant is also reported to be antimicrobial [31]. In addition, an infusion of *Commiphora edulis* was reported to be used against tapeworms. Pinworm infestation was reported to be managed through exposure to smoke from burning seeds of *Ricinus communis*, an application that is likely to be facilitated by the poisonous nature of the seeds [1, 66]. Ringworms were reported to be treated with topical applications of exudate from *Edithcolea grandis* and the fruit juice of *Solanum campylacanthum*. Ringworms are fungal infections [62], locally referred to as "*masilingi*" by the local herbalists and infecting the surface of the skin. *Solanum campylacanthum* is reported to have an antifungal activity [111] supporting its ethnobotanical application in the treatment of ringworms. Skin ailments are mostly treated through direct topical application of herbal preparations [38] although a decoction of *Terminalia prunioides* was also reported to be drunk against ringworms.

Gastrointestinal problems are common health problems in rural areas of Kenya where in some ethnobotanical studies, they have been found to be managed with most of the medicinal plants surveyed [32, 86]. According to the WHO, diarrhea is one of the world's leading killer diseases in children below the age of five [93]. The herbalists associated its outbreak with poor sanitary conditions especially dirty drinking water, which is also a major cause of diarrhea according to the United Nations Children's Fund [109]. Diarrhea was reported to be associated with stomach-ache and constipation as also reported elsewhere [42]. Those ailments were reported by the herbalists to be mostly managed using herbal infusions and decoctions. Some plant species reported for the treatment of gastrointestinal ailments such as *Croton megalocarpus*, *Terminalia brownii,* and *Cissampelos pareira* have been reported to have antimicrobial activities [31, 112, 113]. On two different accounts, the herbalists reported to advising pregnant mothers against taking infusions of *Solanum campylacanthum* and *Cissampelos pareira* for stomach problems as they might induce abortion. However, *Solanum campylacanthum* is reported to play important roles during labor and in maintaining pregnancy [13]. Although medicinal plants may have profound effects on pregnant mothers [114], they also play important roles in the development of fetus and in the health of the mothers [14]. Side effects of medicinal plants may result from improper dosage and the effects may be nonfatal [98]. Peptic ulcers were reported to be treated using an infusion of *Aloe secundiflora* or a decoction of *Terminalia prunioides*. *Aloe secundiflora* is reported to have an antimicrobial activity [115] which further supports its ethnobotanical application. Toothache was reported to be managed using *Solanum campylacanthum*, *Zanthoxylum chalybeum,* and *Ficus sycomorus* where the first two species are reported to have antimicrobial activities [111, 116]. Silver nanoparticles synthesized from the latex and leaves of *Ficus sycomorus* have been found to have a high antibacterial inhibition, proving that the plant has a potential in the treatment of bacterial infections [117]. However, according to one herbalist, the use of *Ficus sycomorus* latex for toothache is dangerous since it might spread in the mouth resulting in the loss of other teeth through corrosion which in turn leads to cracking and splitting of teeth into smaller pieces which fall with time.

Historically, the Kamba people of Kitui were semipastoralists [55, 58] and this culture has persisted to date [53]. Although the present study focused on documentation of medicinal plants used in the management of human diseases, the herbalists reported some plant species used for the management of livestock diseases (Table 5). Future studies are necessary to determine the diversity of plants used for the management of livestock

Table 5: Plant species with ethnoveterinary applications in Mutomo hill plant sanctuary and its environs. Where possible, literature citing ethnoveterinary uses of the reported plant species has been indicated.

Plant species	Part used	Ethnomedicinal applications	Disease treated	Reported ethnoveterinary uses
Commiphora baluensis	Bark	An infusion	Diarrhea in poultry	Diarrhea in chicken [64]
Commiphora habessinica	Exudate	Applied on areas infested with ticks	Deticking agent in goats and cattle	Is antiseptic [64]
Boscia coriacea	Leaves, root	An infusion is administered orally. The leaves are burnt and ground into a powder which is applied into the eyes	Diarrhea in goats and cattle. Partial blindness and eye injuries in cattle	Bile problems in poultry [40]
Kleinia squarrosa	Aerial parts	An infusion	Diarrhea in poultry	Literature not found
Launaea cornuta	Aerial parts	An infusion	Liver diseases in poultry	Diarrhea and coccidiosis in chicken [1, 64]
Croton megalocarpus	Leaves	An infusion	Liver disease in poultry	Diarrhea, dysentery, and swollen heads in poultry [74]
Albizia anthelmintica	Bark	An infusion is administered orally. Dried bark is ground into a powder which is applied into eyes	Liver diseases in poultry, eye injuries in cattle	Deworming and diarrhea in livestock [64]
Plumbago zeylanica	Roots, aerial parts	The roots are burnt and ground into a powder which is applied into injured eyes. An infusion from aerial parts is administered orally in poultry	Eye injury in cattle, lung and liver diseases in poultry	Literature not found
Cissus quadrangularis	Stem	An infusion is administered orally. The plant is sometimes mixed with the bark of *Commiphora baluensis* and *Albizia anthelmintica*	Diarrhea in poultry	Gall diseases, east coast fever, lung trouble, and diarrhea in cattle [64, 65]
Cissus rotundifolia	Leaves	An infusion	Diarrhea in poultry	Bloat, black quarter and anaplasmosis [1]
Aloe secundiflora	Exudate	An infusion	Diarrhea in poultry	Coccidiosis in chicken and diarrhea in livestock [1, 40, 64]

health conditions in the study area and in Kitui county at large.

5. Conclusion and Recommendations

This documentation contributes to safeguarding the indigenous knowledge of medicinal plants in the study area, which might be useful for the future conservation of such plants in the sanctuary. Efficacy studies of the plant species reported, especially the priority plants are necessary to determine their potential in the development of novel drugs. Further studies are necessary to determine the diversity of plant species sold in the urban areas of Kitui, which might be useful for conservation considerations. The herbalists in the study area need capacity building to develop home gardens for the cultivation of the medicinal plants so as to ease the pressure exerted on wild populations. In addition, government institutions involved in biodiversity conservation in Kenya and the county government need to extend their conservation efforts to the Mutomo hill plant sanctuary. Further studies to determine the suitability of the sanctuary for the conservation of medicinal plants are necessary.

Data Availability

The data used to support the findings of this study are included within the article.

Conflicts of Interest

The authors declare that they have no conflicts of interest.

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Ethnobotany of sugar palm (*Arenga pinnata*) in the Sasak Community, Kekait Village, West Nusa Tenggara, Indonesia

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Abstract. *Haryoso A, Zuhud EAM, Hikmat A, Sunkar A, Darusman D. 2020. Ethnobotany of sugar palm (*Arenga pinnata*) in the Sasak Community, Kekait Village, West Nusa Tenggara, Indonesia. Biodiversitas 21: 117-128.* Sugar palm (*Arenga pinnata* Merr.) is one kind of palm that has high potential ecological, economic, and socio-cultural values. This Research aimed to identify the ethnobotanical aspects of sugar palm, especially on aspects related to farmers characteristics, cultivation, utilization, cooking process of palm sugar sap and sugar palm marketing at the Kekait Village, West Lombok District, West Nusa Tenggara Province. Data were collected using participatory observation, in-depth interviews, literature studies, and the selection of informants conducted by purposive sampling. Sugar palm farmers were adult men aged between 42 to 63 years old. They achieved life skills provision from parents to their children. The characteristics of sugar palm farmers in the Sasak community are adult men to the elderly, aged 24-63 years. The source of knowledge about the use of sugar palm is hereditary from parents (father or grandfather). Oil palm farmers in the Sasak community in Kekait Village do not carry out intensive cultivation systems, they still rely on natural services, both regeneration and distribution. The most widely used part of the palm tree is tassel (76.32%), to be tapped. Processing palm sugar into sugar is still carried out with traditional methods and tools, as well as natural ingredients. Sugar palm farmers in Kekait Village were very dependent on small collectors who sell their sugar products. Farmers are in the weakest position in the marketing chains and did not have a bargaining position to determine the price of palm sugar.

Keywords: Lombok island, natural sweetener, Sasak tribe, subsistence, tuak

INTRODUCTION

Sugar palm is a plant with multiple benefits that could be found in several countries in the world, particularly in the region of Tropical Asia (20˚NL-11˚SL) countries. Dransfild et al. (2014) stated about 20 ranging from India, South China, Ryukyus and Taiwan, through Southeast Asia, Malesia including Christmas Island (Indian Ocean) to north Australia, the greatest diversity occurring on the Sunda shelf. It is an endemic plant in Southeast Asian countries. Sugar palm is well distributed in Indonesia. It can be found in almost the Indonesia archipelago. Ministry of Agriculture data (2013) mentioned that sugar palm was well distributed in Indonesia and could be easily found in 14 provinces, included: Papua, Maluku, North Maluku, North Sulawesi, South Sulawesi, Southeast Sulawesi, Central Java, West Java, Banten, South Kalimantan, West Sumatra, North Sumatra, Bengkulu, and Nangroe Aceh Darussalam, within covers of a total area of ± 70 000 hectares.

Indonesia has 1 340 ethnicities (BPS-*Statistics Indonesia*, 2010). Each of these ethnicities groups has a unique use of sugar palm plants in their daily activities. Approximately 150 local names of sugar palm can be found in the territory of Indonesia from Sabang to Merauke reflected that sugar palm is familiar with Indonesian households and multipurpose plants (Zuhud et al. 2014; Kurniawan et al. 2018). According to Anderson et al. (2011), each ethnic group has different perceptions, concepts, management and ways of using sugar palms. Among those ethnicities is Sasak Tribe who lives on Lombok Island. The Sasak Tribe has had economical, ecological, and socio-cultural bound in utilizing sugar palm plants, especially those who lived in Kekait Village, Gunungsari Subdistrict, West Lombok District, West Nusa Tenggara Province. In fact, ties have been firmly established before the area was designated as a village in 1866 (Profile of Kekait village 2017) until nowadays. Sukenti et al. (2016) mentioned that Kekait Village is the best brown sugar producer village in West Lombok District.

Furthermore, they bonded in the identity of the village, as "*Aren Village*," a village with the potential of the natural resources typical of palm trees and the spirit of life of the people who are "Agrarian, Religious, Educative, Naturalist" (AREN). The bounding between sugar palm and the villagers has become the indicator that sugar palm has been utilized by the Sasak Tribe community in Kekait Village for a long time. However, until now the relationship between the Sasak people in the Kekait Village and palm trees has not been well documented. Nonetheless, losing local knowledge on how to utilized plants has continued to increase over time. Therefore, this research is fundamental to conduct.

The research aimed to identify identifies the ethnobotanical aspects of sugar palm, especially on aspects related to farmers characteristics, cultivation, utilization, cooking process of palm sugar sap and palm sugar marketing at the Kekait Village, West Lombok District, West Nusa Tenggara Province, Indonesia.

MATERIALS AND METHODS

Study area

The study was conducted in Kekait Village, Gunungsari Subdistrict, West Lombok District, West Nusa Tenggara Province, Indonesia. Kekait Village area is directly adjacent to Pemenang Barat Village, Pemenang Subdistrict, North Lombok District in the North, Taman Sari Village in the East, Gunungsari Village in the South, and Pusuk Lestari Village and Lembah Sari Village in Batulayar Subdistrict off the West. The village of Kekait has a slightly wet climate or Type C in the Schmidt-Ferguson Climate type classification system. Located at an altitude of 5-650 m above sea level, this village has a hilly topography with 5-40% slope (Figure 1).

Procedures

The types and sources of primary and secondary data related to the ethnobotany of sugar palm and the characteristics of sugar palm farmers were collected using participatory observation, in-depth interviews, and documentation (Cotton 1996; Cunningham 2001; Djamal 2015). In participatory observation, researchers are directly involved in the activities of the research object. Information gathering was carried out by openly interviewing 9 key informants and 110 informants, which were purposively selected. Documentation is done by directly using photos and videos, and indirectly by reviewing government documents or related agencies.

Data analysis

Ethnobotany data analysis of sugar palm and the characteristics of sugar palm farmers were carried out by emical and ethical approaches. Emic approach (knowledge) is arranging patterns of community idea into a system through a list of standard questions obtained through interviews with resource persons. At this stage, a list of all types of local benefits of palm sugar is provided by the resource person (emic). The second approach is the ethical approach (science), which is synthesizing (uniting) various theories into a theoretical research framework. Further beneficial comparison from both approaches was carried out. From this comparison, the confrontation analysis was held to obtain some point of view between community knowledge and modern knowledge (qualitative analysis) (Cotton 1996; Cunningham 2001; Djamal 2015).

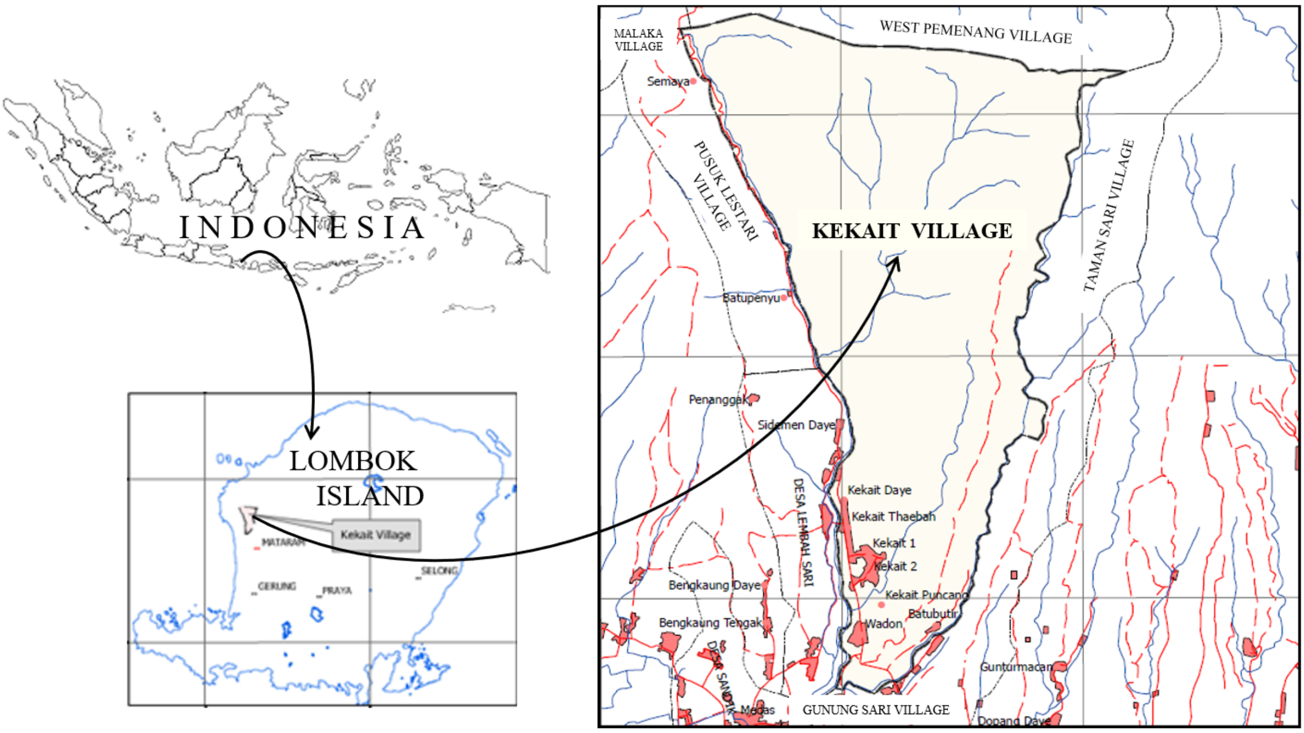

Figure 1. Research location at Kekait Village, Gunungsari Subdistrict, West Lombok District, West Nusa Tenggara Province, Indonesia (8˚28'30"-8˚31'30" S, and 116˚4'30"-116˚7'30" E)

RESULTS AND DISCUSSION

Farmers characteristics

Gender

The observation at the study site found 119 male sugar palm farmers (100%). The male farmers domination in *aren* farming activities was not based on a robust patriarchal system that applies to the Sasak Tribe community, but based on physical demands and time sacrifices of a sugar palm farmer, especially during the process of tapping and cooking palm sap in the Kekait Village. The hard activities that must be carried out by a sugar palm farmer, especially for harvesting sap and other parts caused the women's role has become marginalized. The dealing patterns between men (husbands) and women (wives) roles in the farmer families are inseparable regarding the palm sugar management and exploitation in daily routinely. The same thing was found by Hapsari et al. (2017) in six districts in East Java the majority of men were found working in agriculture during the day, while women were at home. Puspitawati et al. (2018) state that in general, gender roles in agricultural activities, in terms of access and control of agricultural resources, are dominated by men. Role differentiation is a structural prerequisite for family survival. If women must continue to be involved in aren farming (yield utilization) which requires continued presence and time, it will create a family imbalance that can lead to the achievement of wrong family goals (Puspitawati et al. 2018).

Age structure

Age distribution of sugar palm farmers in Kekait Village was ranged from 28 to 67 years old. Based on the developmental age classification determined by the Ministry of Health (2009), the farmers categorized as early adult groups occupied 0.84% of sample, 26.05% late adult, 42.86% early elderly, 29.41% late elderly, and 0.84% old age. The majority of sugar palm farmers were in the early and late elderly groups. The same opinion was conveyed by Widayati et al. (2018) that sugar palm farmers in Muna, Southeast Sulawesi Province are in productive age (42 years). The results indicated that the younger generation in Kekait Village is no longer interested to succeed sugar palm farmers as livelihood sources. Hence this condition continues, the existence of sugar palm farmers in Kekait Village would only become a story in the future, and the extinction of the sugar palm farmers would mean the loss of local knowledge on how utilizing sugar palm.

The lack of interest of the younger generation to succeed palm farmers generally could be due to: internal (farm family) and external (surrounding communities/ coeval, education, government, and technological developments) factors. There could be two causes of why young people do not want to be a sugar palm farmer, firstly: young people assume that dirty sugar palm farmer is not a profession to be proud of. Secondly, most parents (sugar palm farmers) wish their children to get better jobs by sending them to schools as high as possible.

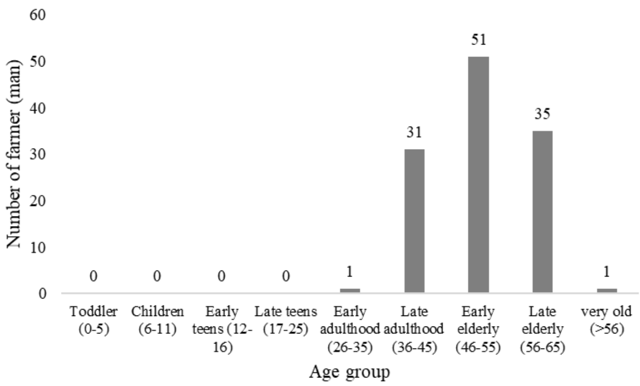

Figure 2. Sugar palm farmers age group distribution

While external factors could be due to the coeval lifestyles in the surrounding environment who works as Indonesian labor migrants (TKI), education system that was not based on local knowledge, the influence of technological developments increasingly alienates the younger generation in its culture, and the lack of government support to the welfare of sugar palm farmers. All of the above factors could discourage young generation to be sugar palm farmers. Parrota et al. (2009) suggested that the ethnobotany knowledge and local practices related to plant resource management are rapidly disappearing due to various factors, such as globalization, infrastructure development, agricultural innovation, tourism development, market interventions, and government policies and regulations. Those factors had impacted the declining concern of traditional wisdom, local knowledge, and lifestyle of young generation. In Kiding Village of Malaysia, the population of *nyok* or *aren* plants was threatened by the younger generations which have lost their interest to maintain aren's sustainability. The knowledge about palm sugar processing is decreased even though the older generation are still planting and preserving it in their area (Lee 2015). These problems are similar to those reported by Hidayati (2017) research in the Baduy community of Banten Province which showed a decline in the level of their local knowledge of plants. Both Lee and Hidayati results indicated that local knowledge is gradually decreased in the inheritance of knowledge to the younger generation.

Source of knowledge

Selapuk penyadep nao dengan mame, laguk ndek selapuk dengan mame tao kance mampu jari penyadep, means that the sugar palm farmers are male, but not all men could become sugar palm farmers, this statement was told by Haji Zaini as the head of Kekait Village. The skill to tap palm sugar is a life skill that should be mastered by boys as a provision for their lives in the future. The boys get the skills hereditary from their parents (father or grandfather) as well as their individual experiences of trial and error processes (Ellen 2006). Hernanto (1989) stated that farming and cultivation of crops and livestock became a culture that was handed down hereditary. Abdullah et al.

(2014); Tamrin et al. (2015); Febriyanti et al. (2017); Gunawan et al. (2018); Withaningsih et al. (2019); suggested that the source of knowledge possessed by palm sugar craftsmen is mostly obtained from parents and they have learned basic skills in business for a long time. The observations results showed a tendency of reducing sugar palm farmers alongside with increasing levels of education. Most of the sugar palm farmers in Kekait Village were lack of higher education background. The higher the educational background of a man, the lower his motivation for working as a farmer as his main livelihood. The interview results showed that out of 114 sugar palm farmers expressed their opinion that knowledge about sugar palm was obtained hereditary, 75.43% of whom got their knowledge directly from parents, especially fathers and grandfathers, while the remaining of 24.57% gained their knowledge by self-study. The process passing of the skill started at the age of 7-8 years old where parents (father or grandfather) had introduced palm trees to their children or grandchildren by taking them to the garden every day.

At the age of 11-12 years old, children or grandchildren were given the task of selling palm sugar to the market or collectors in the village. Later, as the child grew older, he would be taught with tapping skills such as (climbing, cleaning the stem, hitting and rocking flower bunches, and slicing flower bunches) by his parents. Finally, they would learn how to processing sap became sugar palm. Unmarried boys who still live with their parents have an obligation to help their parents farm in the garden. The obligation will be lost where the boy is married and lives separately from his parents. Thus, the knowledge transfer of how to manage and utilize sugar palm from parents to children is a valuable capital for children who consider married and separated from his parents. Mead (1975) as mentioned in Matsumoto and Juang (2004) argued that parenting is an essential way of channeling culture hereditary. Similar things mentioned by Meinarno et al. (2011) that the process of knowledge transfer and culture could be seen in the activities of parents inviting their children to work or going to worship place. In this activity, culture and knowledge are transmitted gradually from the older generation to the younger generation for a long time. The observations results at the study site showed that palm farmers in Kekait Village are currently second generation, third generation, and fourth generation. These results proved that the inheritance of *aren* knowledge passed down hereditary

Livelihood

The most occupied livelihood of the Kekait Village community is farmers, either owned farmers, sharecroppers or farm laborers. There are only small amount occupied as entrepreneurs, teachers, and day laborers. Based on the cultivated land, farmers in Kekait Village could be divided into two professions, which are: dryland farmers and rice farmers (irrigation). The rice farmers dominate dryland farmers. The domination can be seen from the comparison of both land area, 909 hectares of dry land area, and only 17 hectares of wetland area (2017 Kekait Village RPJM). Most dryland farmers are garden farmers, who rely on fulfilling their daily needs from the sap produced by sugar palm trees.

Being a sugar palm farmer, someone must be diligent and disciplined because if the palm tree is ready to be tapped, the farmer should process it every day even in adverse weather conditions (rain, earthquake). Sugar palm farmers rarely have multiple professions since the garden location is far for their home (0.5-6 km), and it needs a routine and continuity to process palm sugar every day. Palm farmers find that it is difficult to manage their time into other professions, such as rice farmers, raising livestock, or trading due to the sugar palm processing activity. In one trip it takes 45 minutes-3 hours from their home to the garden on foot, then harvesting the sap while installing a new sapper in several palm trees (15-30 minutes), the morning and evening (07.00 WITA and 16.00 WITA). Moreover, the sap water should be cooked and poured into mold for 3-4 hours. The length of travel time and the process of taking and cooking palm sugar demands the palm farmers in Kekait Village concentrate only onto single profession. On the contrary, Febriyanti et al. (2017) mentioned that palm farmers in the Sundanese Tribe community of Kasepuhan Pasir Eurih in Sindanglaya Village carried out tapping activities of palm sap after paddy farming or cattle breeding was completed. This is because of the palm garden location situated nearby with the residence (one compact unit).

Landowner

The data collection showed that the majority of sugar palm farmers in Kekait Village used *aren* in their gardens or owned by farmers (*gawah*). Similar condition was mentioned by Tamrin et al. (2015) in South Halmahera, he acknowledges cultivated land by sugar palm farmers is a land that is simply managed, in addition. In addition, Febriyanti et al. (2017) at the Kasepuhan Pasir Eurih community stated that the sugar palm trees utilized by farmers are sugar palm trees in the garden *(talun*) that belonged to the population. Likewise in Karwa, India, palms such as areca nut and coconut are found in community gardens (Baht et al. 2014). Although the majority of sugar palm farmers are owned farmers, however, they only have 0.4-0.5 hectares each of them. Sajogyo (1977) as mentioned in Susilowati and Maulana (2012) stated that farmers with a land area of less than 0.5 ha are included in the category of small-scale farmers. Some farmers said that in the time their parents were still alive, the area of the garden ranged from 2-3 ha. However, after the parents die, the garden area was shared with their children following the inheritance law that applies to Islam. Thus, it is common that at present the majority of sugar palm farmers are small-scale farmers.

Hernanto (1989) mentioned that the agricultural sector carries a heavy burden of problems caused by the clamping of farmland due to the distribution of inheritance reasons. Additionally, neither the dynamics of changes in land ownership nor sale and purchase of land occurred rapidly. The changes of landowners mainly reflected in the phenomenon of mortgaging gardens to obtain capital to become migrant labors abroad, either for themselves or their children. Therefore, if someone has a garden area with an area of more than 1 hectares in one place, then the farmer categorized as sufficient farmer. Land ownership for the Sasak Tribe community in Kekait Village shows both economy ability and social status. Hernanto (1989) emphasized that a community member who controls and/or has a production factor could provide a high position or social status in his environment.

Based on the ownership status of the plantation land, sugar palm farmers in Kekait Village could be classified into two types, which are: farmer and peasant/ sharecroppers. Owned farmers are sugar palm farmers performed in tapping palm trees in their own gardens, while sharecroppers or commonly called "*penyakap*" are Sugar palm farmers whose tapping activities are carried out on other people's land. Sharecroppers do this for several reasons as follows: (i) The owned garden has a massive size (more than ten trees) that the owners needed a help form "*penyaka*p" to tap the sap water; (ii) Garden owner deceased, while there are no descendants could follow their ancestors become a palm sugar farmers; (iii) Garden owner has a severe illness, so they could not be harvesting sap water any longer. Thus, the quality of sap water decrease or damage due to fermented processing; (iv) The aging garden owner could not afford to harvest any, at the same time there are no younger generation of farmers could continue tapping palm sugar palm in their garden; (v) Garden owner become migrant workers abroad, while the younger generation could not continue to tap palm sugar palm in their garden.

The relationship between the *penyakap* and the owner of the garden is based on mutual trust by both parties. Therefore the system which commonly used for the harvesting palm sugar is profit sharing. Profit-sharing methods used in the systems by dividing the tapping yield alternately. It is divided once or in a two days interval considering the volume of yield. The yield should be fulfilled the minimum amount of molded sugar to be sold (generally they sold ten molded-sugar). Hence the minimum amount of molded sugar could be fulfilled in a day; then it is called "daily profit sharing," hereafter if the minimum amount of molded sugar could be fulfilled in 2 days then it is called "alternate profit-sharing." During this research, the commonly used profit-sharing system was a lapse of one day, while the daily system was rarely found. The payment from the molded sugar sales received by the *penyakap* did not be deposited every day or intervals day, but two weeks or once a month to the garden owner.

Ethnobotanical aspect of *Arenga pinnata*

Cultivation system

Sugar palm in the Kekait Village cultivated naturally by the farmers within a less human intervention. This condition could be seen from the spacing distance among the sugar palm trees which are not uniform. Besides, the number of palm sugar saplings clustered around the main trees. Palm farmers would do thinning if only the survived juveniles are clumps very densely. For example, there is 6 clustered juveniles sugar palm, and then the farmers would reduce two juveniles sugar palm. The undertaken action was to provide sufficient space for the development of other four juveniles. The selected juvenile is considered the worst which has physical conditions as mentioned: growth slowly, fewer midribs, and leaf midribs more rigid when compared to others that are close together. Murtado et al. (2014) mentioned there are not many people have cultivated sugar palm plants because large-scale propagation technology has not been mastered until nowadays. Moreover, research on post-harvest technology and preservation of palm sap is still lacking, and business management is also still weak. Related to this statement, Lempang (2012); Yuldiati et al. (2016); Surya et al. (2018) stated that the demand for products whose raw materials from palm trees so far have been fulfilled from wild palm trees.

Most sugar palm farmers believe that some saplings lived farther from the main trees are distributed by animals help, such as "*ujat*" or Rinjani Weasel (*Paradoxurus hermaphroditus rindjanicus*). Similiar condition applied in the Cipanggulan community, Cianjur District. Although palm trees provide benefits for some people, nonetheless the community does not carry out intensive cultivation. Hence palm trees could be found in various places because of the civet or palm civet's (*Paradoxurus hermaphroditus pallas*) help (Gunawan et al. 2018). Campbell et al. (2008) revealed that complex hormone interactions produced edible fruit and lured the animals to spread the seeds. The ripe palm sugar eaten by civet would be digested through the digestive process (Iskandar et al. 2016; Partasasmita et al. 2016). However, the sugar palm seeds in it will not be digested and released along with the feces (*endozoochory)*. Palm farmers believe that sugar palm seeds that came out from ujat's feces would become growth faster seeds, compared to palm seeds that are naturally embedded around the main trees. In consequence, the Kekait Village community, particularly sugar palm farmers prohibit ujat's hunting. As a result of relying on natural regeneration, there was lack of stapped palm trees at a specific time which generally called famine time**.**

The utilized part of palm tree

The Sasak Tribe community in Kekait Village places palm trees in a unique position as a "gift" tree or blessing tree. Palm trees are a gift from Allah Subhanahu wa Ta'ala (God) with many benefits that could not be compared to other types of trees. All parts of the palm tree including roots, stems (deep or pith, outside or peripheral), leaves (young and old), fruits, and flowers could be utilized (Table 1). Gunawan et al. (2018) mentioned the same thing in the Cipanggulan community, Cianjur District, West Java Province that sugar palm is a vital plant compared to other types of plants, all parts of sugar palm plants could be utilized from roots, stems, fibers, leaves, fruits, and flowers. Although all parts of the palm tree could be utilized, not all parts could be used simultaneously. To be able to use the sugar palm, farmers in Kekait Village naturally have two choices to utilize: cutting down or not cutting down the palm trees. Should they choose to cut down the trees, the parts of the tree that could be utilized economically are the stems for making sago flour and palm fiber. The cutting down trees is one time only harvesting during the life cycle and sugar palm trees perished.

Table 1. the utilized part of sugar palm

Parts	Utilization	Percentage of part being utilized (%)
Root	As a traditional medicine to cure bladder disease, urinoir infection, and arthritic	0.88
Inner stem	As sago flour ingredients, while the dregs are utilized for mushroom backlogs	3.51
Outer stem	As a gutter, hoe handles, cooking and household utensils, and firewood	2.63
Leaf midrib	As an ingredient in making *kodong* or fish trap	0.88
midvein	As primary material in making broomsticks and plates	0.88
Young leaves	As a tobacco wrapper (traditional cigarette)	1.75
Old leaves	As a traditional food wrapping material, ornaments of traditional events	0.88
Flowers bunch	As a leading source for making palm sugar, fresh sap water both as a cure for diabetes and sprue, fresh flowers for animal feed and dried panicles are used as crafts	**76.32**
Fruits	As a source of healthy food, commonly referred to as *kolang-kaling* or bêluluk by the Sasak people, the remaining skin of fruit is used as animal feed	6.14
Palm fiber	As a material for traditional building roofs, palm brooms, absorbing household waste, reinforcing water dams, and traditional house ornaments known as *gelengan*	6.14

Conversely, if the trees do not cut down, the parts of the tree that could be utilized economically are palm sugar from flowers, *kolang kaling* from fruit, and palm fiber (*ijuk*). The use of palm sugar from flowers could be done several times periodically in 1 life cycle of palm trees, one flower bunch can be tapped 3-4 months every day (morning and evening), and the palm regeneration process could be adequately maintained because the farmers in Kekait Village always leave 1-2 fruit bunches to obtain *kolang kaling*. In this case, the majority of sugar palm farmers in Kekait Village prefer the second method of utilization which is not cutting down palm trees. This means that the local wisdom activities of utilizing sugar palm trees wisely could guarantee the fulfillment of life needs sustainably.

The majority of sugar palm farmers in Kekait Village have chosen sap water to be processed into palm sugar or commonly called *cupak* sugar. The word "*cupak"* is taken from the name of a molder from bamboo made to mold sugar palm and known as *cupak* by the community. Lempang (2012) stated that molded sugars generally have the shape according to the shape of the mold being used. Palm sugar has a unique position in the culture and daily life of the Sasak Tribe community. For example in the elopement (*adat kawin lari*) in the Sasak community or *mêrariq*, palm sugar becomes a "breaker" at the *sorong serah* ceremony, which is one part of the tradition of elopement which most determined the validity of marriage. If all the *ajikrama* (traditional bailing) has been calculated and there is no shortage at all, all the items will be lifted onto the *berugak*, place of the ceremony. Then a Kyai (Islam's religious leader) took the brown sugar that was tucked among the *ajikrama*, then it would be broken down into small pieces and shared it with all those present to eat, as a sign of the agreement of all community leaders and religious leaders to the marriage. Yasin (2008) implied *mêrariq* is a genuine local culture and ritual from the Sasak community ancestor which still exists nowadays.

Palm sugar also has essential position for the community as a sweetener for traditional foods and drinks of Sasak Tribe, such as *kêraké, gulasari, pumpkin tumbêk, palm coffee, and, sherbet*. Sukenti et al. (2016) pointed out that *A. pinnata Merr.* included in 10 species of plants that are widely used by the Sasak people. It is used for daily life, traditional, and religious ceremonies as food and beverage sweeteners. The high utilization of sap becomes palm sugar is inseparable from the religious background of the majority Kekait Village community, which is Islam religion that prohibits drinking alcoholic beverages (*tuak*). Unlike the Batang Toru community in North Sumatra, palm sugar is mostly processed into *tuak*, because the majority of the people have Christianity backgrounds who do not prohibit drinking alcoholic beverages such as palm wine (Martini et al. 2012).

Palm sugar sapping process

Palm sugar farmers in Kekait Village have been implementing stages in tapping sap from flower bunches (*pêji*) so that they could be tapped for generations. As Tamrin et al. (2015) in South Halmahera, and Febriyanti et al. (2017) in Banten, the molding processes of sugar palm is done with simple equipment, such as bamboo, cauldron or pan, clay furnace. While Gunawan et al. (2018) mention several stages of harvesting palm sugar in Cipanggulan community, Cianjur District from climbing *aren* trees using bamboo ladders, cleaning leaf midribs, hitting and swinging bunches, and tapping palm sugar palm juice. The stages of tapping palm sugar in the Sasak community in Kekait Village, West Nusa Tenggara are as follows:

First process. Sap water processing would be done as soon as possible after the sap scent from the flower fissured. The typical scent from the palm sugar known as *mambu angin* or *bou angin* by the farmers. Local sugar palm farmers interpret the scent as a distinctive aroma of palm sugar which begins to burst and then carried out by the wind until sugar palm farmers faintly smell it.

Second process. In addition to the bursting flower, the farmers would ensure that some flowers have begun to fissure. After capturing the signal, the farmers made several preparations. The preparations are making a ladder (*sanggéng*) made from bamboo stick or *tréng galah (Gigantochloa atter)* as a tool for farmers to climb palm trees; cleaning out the midribs leaf; cleaning out the fibers (*njuk*) which cover the stem using *parang timpas* (*batéq timpas*); cleaning the flower bunches from the flower petals (*seludang*) and tie it to the tree above to avoid broken flower bunches. Tying the flower bunches is important because the flower panicle's weight would increase every day, broken bunches could not produce sap water when it sliced (*pêsuk*). Cleaning midribs steam activities from the midribs palm fibers and flower petals are called *ngélah* (Figure 3.A).

Third process. After 2-3 days of *mambu angin* (no. 1), sugar palm farmers will hit (*mantokin*) and shake (*bêgéyong*) flower bunches (Figures 3.B-C). Kurniawan et al. 2018) stated knocking neera is an important step because neera tends to degrade immediately and cause poor quality palm sugar. The circumstances of hitting and shaking the bunch of flowers called the *bakêt*. Beating is carried out evenly throughout the flower bunches, from the base attached to the stem to the border of the flower pan. Based on the observations, farmers hit the flower bunch for ± 10 minutes with total hit for nearly ± 200 times. While shaking the bunch of flowers as much as ± 40 times in one series (1 *bakêt*). As an illustration, the amount of *bakêt* in flower bunches can be seen in Table 2. Based on the experience of sugar palm farmers who have been harvesting for decades, the number hitting and shaking the flower bunches or bakêt depends on the flower bunch be tapped. Generally, the first arenaceous flowers (*puniq*) get more bakêt than the second or so on appearance (*langkék*). The first palm flower is 6 *bakêt* (50 days), while the second palm flower and so on are fewer, only 4 *bakê*t (34 days).

Fourth process. After completing 3 stages of tapping preparation, the farmer would cut the palm flower bunches using special machetes. *Parang* (machete) has a sharp side and a very thin blade that resembles the "S" letter, commonly called *sadep*. Farmers would cut the palm flower right at the top of the flower panicle (Figure 3.D). Based on the interview, some palm farmers usually had a dream of flood at the night before the cutting process is held, as a sign that the flower bunch would be diligently dripping (*pacu)*. After cutting the flower bunch, the farmer then would thinly slice the ends of the flower bunches (15-20 slices) until the dripping is smooth (*bongar*), then at the ends of the slice are cleaned up using hand palms and clean water (*pêrêsik*). The next step is to install the palm sugar container in the form of clay pots (*bongs*), bamboo (*bumbung*), or jerry cans. However, before putting the sap water into the container, the farmers would add a natural preservative into the sap water.

The natural preservatives of sap water are in a wood form (stems or roots) or leaves of certain tree species that farmers get knowledge hereditary. The farmer refers to the natural preservatives as *pakêt.* The same opinion was expressed by Withaningsih et al. (2019), that the farmers in Sukaresmi, West Bandung gained knowledge about palm sugar management through independent learning The observation results revealed that there were four species of plants used as *pakêt*, namely: *purut* wood (*Dysoxylum parasiticum* Osbeck.), *badung* wood (*Garcinia parvifolia* (Miq.) Miq.), *mundah* leaves (*Garcinia dulcis* (Roxb.) Kurz.), and *bintangur* leaves (*Callophylum soulatri* Burm. f.). Palm sugar farmers in Kekait Village mostly use *purut* wood (*Dysoxylum parasiticum* Osbeck.) as the main choice of *pakêt*. Sugar palm farmers use their instincts and experiences in determining the right size of pakêt to be put into a palm sugar container by paying attention to the previous results of sapper reservoir.

Table 2. The amount of bakêt treated to flower bunch

Bakêt (series)	Period days	Treatment to flower bunch	Type of bunch
First (*Sekék*)	3	Beating is carried out evenly throughout the flower bunches, from the base attached to the stem to the border of the flower pan. The flower shook once in a day for three days consecutively	First flower, second flower, etc.
	7	Break	
Second (*Duê*)	1	Beating is carried out evenly throughout the flower bunches, from the base attached to the stem to the border of the flower pan. The flower shook once in a day	First flower, second flower, etc.
	7	Break	
Third (*Têlu*)	1	Beating is carried out evenly throughout the flower bunches, from the base attached to the stem to the border of the flower pan. The flower shook once in a day	First flower, second flower, etc.
	7	Break	
Fourth (*Mpat*)	1	Beating is carried out evenly throughout the flower bunches, from the base attached to the stem to the border of the flower pan. The flower shooked once in a day	First flower
	7	Break	
Fifth (*Limê*)	1	Beating is carried out evenly throughout the flower bunches, from the base attached to the stem to the border of the flower pan. The flower shooked once in a day	First flower
	7	Break	
Sixth (*Nêm*)	1	Beating is carried out evenly throughout the flower bunches, from the base attached to the stem to the border of the flower pan. The flower shooked once in a day	-
	7	Break	

Note: Not all logs could be used as a tool to hit the a*ren* bunch. Sugar palm farmers in Kekait Village only use *boroq* or *dadap* logs (*Erythrina subumrans* (Hassk.) Merr.). The *boroq* logs to be used as a paddle should have comparable size regards to flower bunch that would be hit. The small-sized paddle could not affect the smooth flow of palm sap from the flower bunches, meanwhile, large-sized paddle could damage the vessels in the flower bunches (broken), so that the palm sap does not come out of the flower bunches

As the benchmark, the *purut* wood used to preserve 51 palm sugar are as the amount size of adult hands. Astuti (2018) stated that the addition of 1% of *purut* wood from the weight of palm sap, is able to maintain the quality of sugar palm for 24 hours. It turns out that the use of *purut* wood could prevent the growth of *Saccharomyces cerevisiae* in damaging the freshness of the sap water. Rumokoi (1990) in Lempang (2012) mentioned that the dominant microorganisms in the sap fermentation are *Saccharomyces cerevisiae*, in addition to other yeast types, such as *Schizosaccharomyces* sp. and *Candida* sp.

Fifth process. Farmers would pick up the results of tapping as well as installed new sap water container twice a day in the morning (06.00-07.00 WITA) and in the afternoon (15.00-16.00 WITA) (Figure 3.E). During the sap water harvesting process (3-4 months) the farmers must be in an ethical and clean mood, must not commit disgraceful deeds, and must not fight with their wives. If the farmers are in a depressed mood, they believed that the palm tree would get angry and would stop dripping. This means that sugar palm farmers must be diligent, disciplined, and focused on the tapping process, so that the palm juice that comes out of the flower bunches is in line with expectations, smooth and plenty. The sap water that has been picked up from storage has to be cooked immediately because if it is left too long, the sap water would quickly become acidic. Since the sap water too acidic or damaged the ap water could not be molded even though the sap water had been cooked for a long time. Ain et al. (2014) stated that the longer the storage time of sap water, it would reduce the pH value and increased the solid solution of energy sources for bacteria; consequently, the sap water is damaged. Regard to the nature of sap water which is fast acidic, as well as the location of the palm garden that is far from the place of residence, each palm sugar farmer must have a working hut in his garden, commonly called *sakan.*

Sap water cooking process

In the sap water cooking process into molded palm sugar, the most vital part to consider is the quality of the raw materials used, which is the quality of sap water from the flower bunch. Palm sugar farmers in Kekait Village have been known for long of three levels of palm sugar simply based on characteristics that how can be felt, seen, and touched directly. They called it *manis sêgêr, sêmêdah, nyêlan*. Palm sugar with *manis sêgêr* quality is sap water with the best quality, has a sweet and fresh taste resembling the taste of coconut water, clear and not sticky even though it has been touched for long time. The medium quality or *sêmêdah*, the taste of sap begins to sour, somewhat cloudy and slightly sticky even touched for a while. Poor quality is usually called *nyêlan*; it feels very sour, cloudy and bubbly, and feels sticky when touched by hand. Palm sugar farmers in Kekait Village only use excellent and medium quality of sap water to be cooked into palm sugar.

After ensuring that the sap is of good or moderate quality, the farmer would immediately cook the sap water on the fireplace made of a mixture of clay and sand (*sêronggé*) in the work hut. Farmers cooked sap water every day in two types of the cooking process, namely half-cooked and fully cooked, depending on the volume of sap resulted in tapping activities. Half-cooked process, if the volume of tapped sap water less than 25 liters, while fully cooked process held if the volume of tapped sap water more than 25 liters. The fully cooked process is held by sugar palm farmers to produce ten molded palm sugar (*cupak* sugar) at a time, considering the current system of selling palm sugar in Kekait Village, which is sold every ten molded palm sugar. Tamrin et al. (2015) mentioned that palm sugar in South Halmahera is cooked every four days, whereas in the community of Kasepuhan Pasir Eurih the cooked of palm sugar is held once in three days Febriyanti et al. (2017).

It took 3-4 hours in one cooking cycle process. Amin et al. (2010) and Nankean et al. (2013) stated that cooking sugar palm juice traditionally for a long time can maintain the antioxidant component in palm sugar. Starting with the preparation stage, i.e.; clean up the furnace by removing the rest of the previous combustion, washing the large cauldron (vase), stirrer made of palm midrib (*penggarung*), wood spoon (canting); wash and soak the sugar molders made of bamboo (*cupak*) using clean water. The next step is filtering the sap water two times. The first filtering is held to clean the sap water from the dirt which included sap water from container by pouring it from a container into a bucket. The second filtering is held by pouring the sap water from the bucket into a large cauldron which aimed to reduce white foam.

Furthermore, the cooking process started by lighting a fire in the furnace. The farmer uses massive fire at the beginning of the palm sugar cooking process. The sap water would be boiled for the first 30 minutes, marked by the appearance of white bubbles. The next minute after the appearance of white bubbles, it would be decreased as a sign that the water content started to decrease due to evaporation and the remaining is sugar liquid. The color of the sap water turned into light brown, entering the 60th minute the color of sap water gets brown. The caramelization signs begin to form (*bolo*). In the 75th minute, liquid sugar forms brown bubbles, as a second boiling sign (*bangkal keduê*) occurs; generally, the bubbles produced are higher than the first boil. The farmers added a little grated hazelnut seed (*Aleurites moluccana* (l.) Willd.) to reduce bubbles so the bubbles could not be spilled of the cauldron. The process of adding hazelnut seed is called *nglekongin*, from the basic word of *nlekong* which means hazelnut in Sasak language. According to Istriyani (2011), the oil content in hazelnut seeds is high, which is reach 55-66% of the weight of the seeds, this allows them to be used as a natural candle so that it could be made the hardening of palm sugar durable. Supposed the hazelnut seed unavailable, the farmers used a little grated coconut (*Cocos nucifera* L.) instead. For one cooking cycle process, the farmers need to add grated hazelnut or coconut fruit as much as 0.5-1 teaspoons. Adding too much-grated hazelnut or coconut fruit would actually reduce the quality of palm sugar.

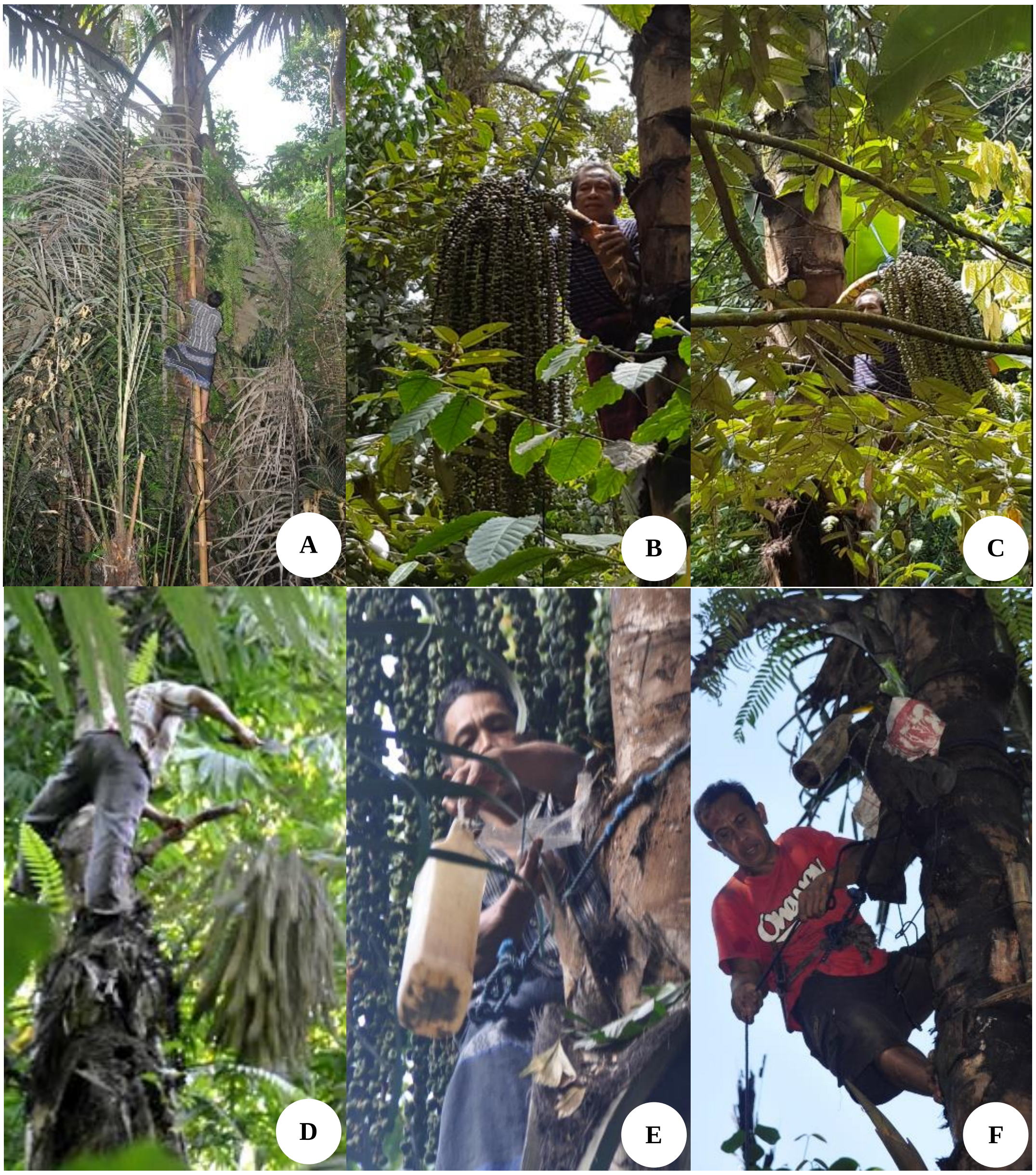

Figure 3. Palm sugar sapping process. A. Installing bamboo ladder, cleaning palm fibers, B. Hitting the flower bunch, C. Shaking the flower bunch, D. Cutting the flower, E. Install and replacing the container

In the 90th minute, the sugar will experience thickening (kêbêq). At this stage, the farmers would conduct a simple test to find out whether palm sugar can later be molded or not. The test is held by taking a little palm sugar and then dipping it into clean water for a moment, then throwing it back to the edge of the cauldron. If the throw produced a "tak" sound, the farmer would be smiling happily, since cooked palm sugar could be molded. On the contrary, where the throw did not produce a sound, it indicated that palm sugar could not be molded. The test also concluded that in a moment the cauldron should be taken off from the furnace and the fireplace should be reduced by pulling a little firewood out of the furnace. The cauldron was taken off from the furnace (± 120 minutes), then the sugar started to be stirred from the center towards the cauldron edge counterclockwise for ± 60 minutes periodically. The stirring process is conducted to speed up evaporation of heat. For farmers in Kekait Village, which are predominantly Muslim, the direction of the rotation is described as activities surrounding the Ka'bah in a series of Hajj (tawaf) services. They always pray to be able to fulfill one of the Pillars of Islam from the business of palm sugar. Thus, it is not surprising that sugar palm farmers who have been able to fulfill the Hajj are highly respected in Kekait Village.

The stirring stage would be stopped soon after the sugar fibers appear while stirring (± 180 minutes) as a sign of palm sugar ready to be molded. Consecutively, the liquids are poured into bamboo molds (*cupak*) which have been soaked before. Sugar palm farmers rely on their intuition experiences in making molded palm sugar. The bamboo used as molders has a diameter of three adult fingers and three-quarters of the height of an adult's palm. Hence, it is not surprising that palm sugar produced varies significantly in size. In the 195th minutes, the sugar mold was reversed, and a moment later it was removed. Having confirmed the palm sugar cold and hardened, the palm sugar wrapped in dried banana leaves or barrel (± 240 minutes), and palm sugar is ready to put into market. Tamrin et al. (2015) said that palm sugar in South Halmahera was packed using dried banana leaves and then ready to be marketed, while Febriyanti et al. (2017) explained that in the community of Kasepuhan Pasir Eurih besides being packaged using dried banana leaves, palm sugar can be packaged using dried bark leaves, tied and ready to be marketed. According to the farmers, the use of dried banana leaves is not only easily available in the garden and organic but also able to maintain the distinctive aroma of palm sugar. The process of cooking sap into palm sugar can be seen in Figure 4.

Palm sugar marketing

Marketing process of palm sugar from farmers to consumers is observed in three marketing channels, which are: zero-level, three-level, and four-level marketing channels, within local to national scale market ranges (Figure 5). The vast number of levels in the marketing channel shows the number of traders between pre to post arrives the palm sugar in the consumers. The zero level channel, or often called direct marketing, is the process of channeling palm sugar from farmers as producers to the consumers without intermediaries. The three-tier channel is a marketing channel with three intermediate traders; village collectors, large collectors in the province, and retailers. While the four-level channel is a marketing channel with four intermediary traders, namely: village collectors, large collectors in the province, large collectors outside the province and retailers. Soekartawi (1989) stated that each marketing institution following its financing capability would carry out marketing functions differently.

Figure 4 sap water cooking process into palm sugar

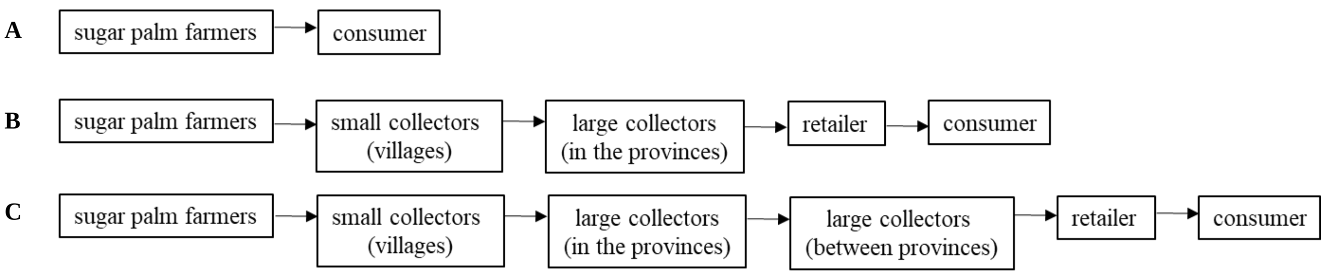

Figure 5. Palm sugar marketing process from farmers to consumers. A. Zero level marketing channel; B. Three-level marketing channel; C. Four-level marketing channel

Sugar palm farmers in Kekait Village often sold their palm sugar to the village collectors. The same thing was found by Hidayat et al (2016) palm farmers in Capar Village, Brebes District, Central Java prefer to sell palm sugar to collectors so that they can quickly get cash to meet the needs of family members. Based on the field observations it was found 24 village collectors. Village collectors can be divided into two based on their village origin: village collectors who are residents of Kekait Village and outside Kekait Village, each of it 20 and 4 people consecutively. Each village collector has established a bond of trust with 10-15 sugar palm farmers over the years. Bonds are established because the farmers are heavily relying on the sale of palm sugar in order to fulfill their daily needs, while the collectors are willing to pay cash for each palm sugar produced by farmers at that time. For this case, pricing and market information are controlled by village collectors, so farmers could not either determine the price of palm sugar as their wishes or bargained with the collectors. Riyadh (2018) stated that up to now, the supply and value chain or agricultural products in Indonesia have not been efficient. One indicator is the length of the marketing chain of agricultural products from farmers to consumers

In conclusion, the characteristics of sugar palm farmers in the Sasak community were adult men to elderly people, aged 24-63 years old. The skill of how to process sugar palm was passed hereditary from parents or grandparents to their children or grandchildren. Sugar palm farmers in the Sasak community in Kekait Village do not carry out intensive cultivation systems, they relied on nature, both regeneration and distribution. The most widely used parts of the palm tree were the flower bunch (76.32%), to be tapped. Processing palm sugar into sugar was still carried out with traditional methods and tools, as well as natural ingredients. Sugar palm farmers in Kekait Village were very dependent on small collectors to sell their sugar products. Farmers were in the weakest position in the marketing channel pattern and do not have a bargaining position to determine the price of palm sugar.

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Ethnobotanical investigation of spice and condiment plants used by the Taming tribe in Aceh, Indonesia

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Abstract. *Navia ZI, Audira D, Afifah N, Turnip K, Nuarini, Suwardi AB. 2020. Ethnobotanical investigation of spice and condiment plants used by the Taming tribe in Aceh, Indonesia. Biodiversitas 21: 4467-4473.* Communities are inseparable from plants in meeting their daily food needs, especially plants as supplementary food. The aim of this study was to investigate of ethnobotany and economic value of spice and condiment plants used by Tamiang tribe in Aceh, Indonesia. A field survey was conducted in three sub-districts, namely Rantau, Seruwai, and Bendahara, Aceh Tamiang District involved 150 respondents (50 individuals from each sub-district) were randomly selected. A total of 31 spices and condiments plants consisting of 26 genera and 18 families was recorded in the study area. Fruits (36%) are the most commonly used parts of plants for spices and condiments, followed by leaves (16%), seeds (13%), rhizome and flower (10% respectively), bulb (6%), and stem and bark (3% respectively). These species were used for preserving traditional cuisines such as *bubur pedas*, *ikan cang rebong*, and *anyang*. *Capsicum annuum* L has high economic value. The Tamiang tribe has always preserved traditional knowledge of the use of various spices and condiment plants for traditional cuisine.

Keywords: Aceh Tamiang, biodiversity**,** economics, Tamiang tribe, traditional cuisine

INTRODUCTION

Spices and condiments plants are biological resources that have played an important role in human life for a long time, have been applied to the natural plant or vegetable products and mixtures of seeds in whole or ground form to enhance the flavor or aroma of food or drinks (Rathore and Shekhawat 2008; Gadegbeku et al. 2014). Approximately 400-500 species of spices are found in the world and 275 species are found in Southeast Asia (Hakim 2015). Sixty-nine of spice plants were used by local communities in Aceh Jaya district (Aqilah 2017), 34 species in Banyumas (Apriliani et al. 2014), and 19 species by Kanayatn Tribe in Kalimantan (Manangka et al. 2017). Several important species, including *Amomum compactum* Sol. ex Maton, *Cinnamomum verum* J. Presl, *Syzygium aromaticum* (L.) Merr. & L.M.Perry, *Zingiber officinale* Roscoe, *Myristica fragrans* Houtt., and *Piper nigrum* L. are important spices plants in Indonesia. In addition, condiments are a mixture of herbs and spices blended in a liquid form (Manoj et al. 2004; Kumar and Singh 2014). Spices are therefore plants or plant products that are usually added during cooking or preparation, while condiments are plants or plant products that are added to a table of prepared food (Agize 2014; Gadegbeku et al. 2014). Spices and condiments are commonly aromatic and pungent (Achinewu et al. 1995) and are mainly used for improving the color, fragrance, and taste (Bharali et al. 2017).

The Tamiang tribe is a tribe living in the Aceh Tamiang region, Aceh Province, Indonesia were used various spices and condiments plants as food, medicine, and traditional ceremonies. These species have been found either wild or cultivated in farmland or the home garden. In general, the Tamiang tribe uses different species of spices and condiments as ingredients in traditional dishes such as *bubur pedas*, *ikan cang rebong* and *anyang*. This food is distinctive and rich in spices, salty, and spicy and is usually served at traditional cuisine. Aqilah (2017) reported that Aceh province rich in traditional cuisine such as *gule plik, i bu pedah, kuah belangong, bu minyek, asam ue, pet udeng, gule boh panah, sie masak mirah, tumeh eungkot muloh, ayam tangkap, urap on peugaga, keumamah*. These foods are known to be rich in spices (Arif et al. 2013). In principle, the culinary richness and uniqueness of the traditional cuisine cannot be separated from the diversity of spices plants that grow in a different habitat. Various plants are known to be rich in nutrients and bioactive compounds that are important to human health (Navia and Chikmawati 2015; Elfrida et al. 2020; Suwardi et al. 2020a), including spices and condiment plants. However, modernization and changes in consumption patterns pose a serious threat to the future existence of spices and condiments plants (Hakim et al. 2015). In addition, the loss of species in different regions is also affected by the decline in the traditional knowledge of the local community on the use of various plant species (Maheshwari et al. 2018; Suwardi et al. 2019; Navia et al. 2019a) including spices and condiments.

Ethnobotanical knowledge has a vital role to play in the management of natural resources. This knowledge was passed down from generation to generation (Tamin and Albain 1995). Ethnobotany studies the relationship between human beings and plants, not only their use, but also ecological, economic, social, and culture (Maheshwari et al. 2018; Suwardi et al. 2018; Supiandi et al. 2019; Mulu et al. 2020). Ethnobotany can be used as a method to record the traditional knowledge of the local communities that have used various plants to support their livelihoods (Suryadarma 2010; Navia et al. 2020; Suwardi et al. 2020b; Suwardi et al. 2020c). Given the lack of data on spice used in the traditional Aceh Tamiang people's dishes, ethnobotany studies are needed. The aim of this study was to investigate of ethnobotany and economic value of spice and condiment plants used by Tamiang Tribe in Aceh, Indonesia.

MATERIALS AND METHODS

The study area

Aceh Tamiang District od Aceh Province, Indonesia is located between 4°20'54.8"N, 98°03'47.5"E. Climatic conditions in Aceh Tamiang District are tropical humid, having an average rainfall varying 353 mm-3660 mm, and the average daily temperature of the area is 29°C (Central Bureau of Statistics of Aceh Tamiang District 2020). The study was conducted from March to May 2019 at Aceh Tamiang District, Aceh Province. The research sites are situated in the Rantau, Seruwai, and Bendahara sub-districts (Figure 1).

Data collection

A field survey was conducted in three sub-districts, namely Rantau, Seruwai, and Bendahara, Aceh Tamiang District. A total of 150 respondents (50 individuals from each sub-district) were randomly sampled (Table 1). The interview was conducted face to face and each interview lasted between 20 and 60 minutes. The interview used a questionnaire consisting of several pages, including plant species, vernacular names, uses, parts usage, preparation methods, economic value, and selling price.

The samples of plants were collected along with reporting their vernacular names, the number of species, and use. The identification of plant species is carried out at the Biology Laboratory Samudra University, Aceh, Indonesia. The botanical names have been updated using The Plant List (www.theplantlist.org), Plants of the World online (http://www.plantsoftheworldonline.org), and the International Plant Name Index (www.ipni.org).

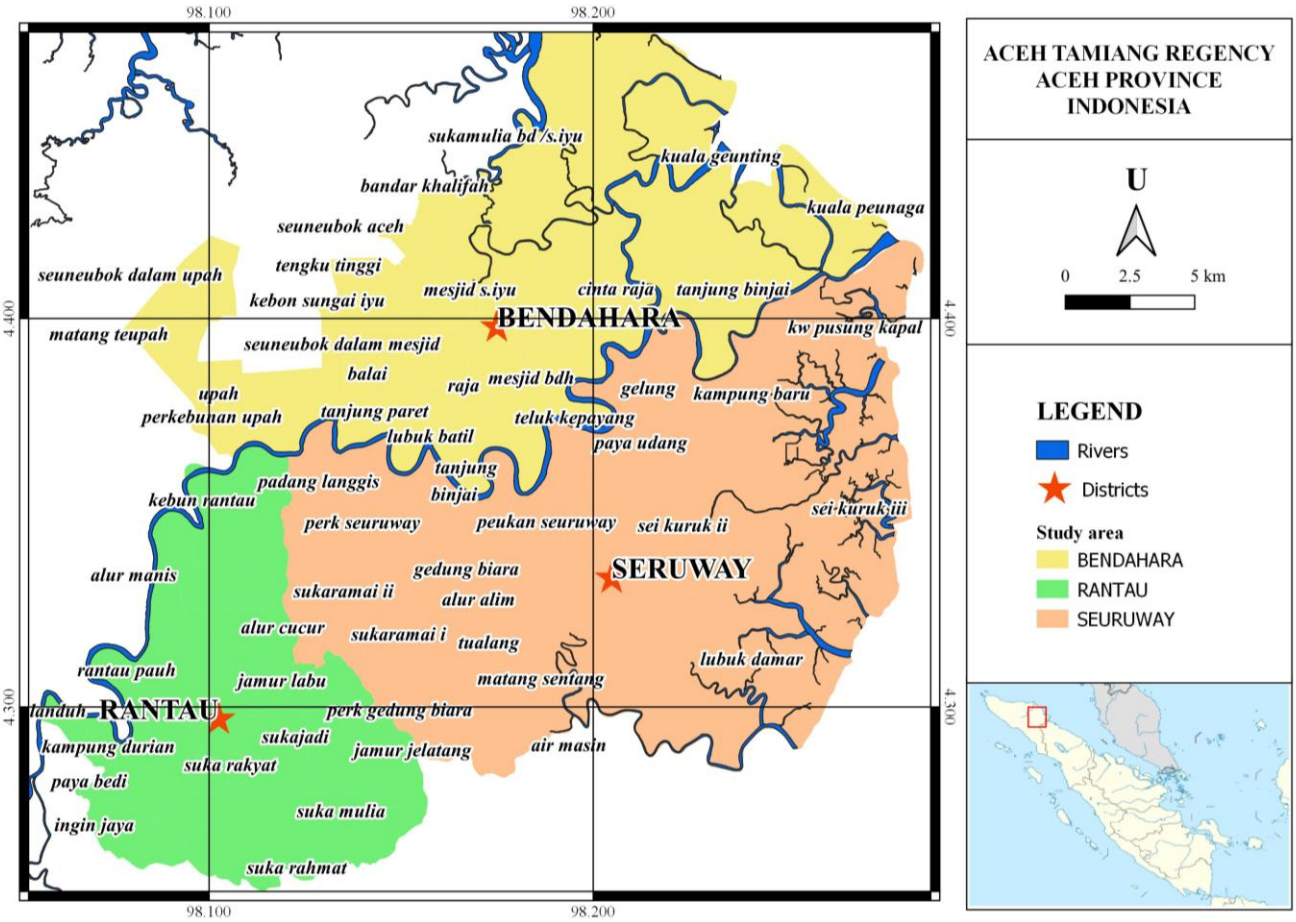

Figure 1. Map of Aceh Tamiang District, Aceh Province, Indonesia, showing the study area

Table 1. The demographic structure of respondents

Parameter	Specification	Frequency	Percentage
Gender	Female	150	100%
Age	Youth (20–35)	30	20%
	Adult (36–64)	80	53%
	Elder (>65)	40	27%
Education	None	10	7%
	Elementary School	9	6%
	Yunior High School	21	14%
	Senior High School	89	59%
	University	21	14%

Data analysis

To compare the relative importance of each plant species, the frequency index was calculated. According to Mahwasane et al. (2013), the frequency index is a numerical expression of the percentage frequency of citation for a single plant species by informants. The following formula was used to calculate the frequency index (Madikizela et al. 2012):

$$FI = FC/N \times 100$$

Where: FC is the number of informants who mentioned the use of the plant species, and N is the total number of informants in each area. The frequency index was high when many informants mentioned a particular plant and low when there were few reports.

RESULTS AND DISCUSSION

Diversity of plants used as spice and condiments

The results show that the plants of the study area are rich in useful, which includes a total of 31 spices and condiments plants belonging to 26 genera and 18 families (Table 2).

Allium cepa L, *A. sativum* L, *Capsicum annuum* L. are common spices and condiments plants have been found in the study area (FI = 100%). However, *Citrus amblycarpa* (Hassk.) Ochse is rarely found in the study area (FI = 18.67%). Zingiberaceae is the dominant family found in the study area with 5 species, followed by Rutaceae (4 species), Apiaceae (3 species), and Amaryllidaceae, Lamiaceae, Myrtaceae, and Solanaceae (2 species each). Zingiberaceae is widely used by the Tamiang tribe as a spice in cooking and consistent with the reported in Northeast India (Gudade et al. 2015; Chakraborty and Chaturvedi 2015; Salam and Jamir 2016) and in West Kalimantan, Indonesia (Robi et al. 2019).

The average number of species identified by each age group of the respondent ranged from 8.5 ± 1.21 (20-30 years) to 44.10 ± 0.01 (> 65 years). In addition, the average number of species identified by each educational status of the respondent ranged from 12.8 ± 2.01 (University) to 33.18 ± 2.11 Elementary School). Some plants were recognized by all respondents include bawang mirah (*A. cepa*), bawang puteh (*A. sativum*), and cabe mirah (*C. annuum*). On the contrary, some other species were familiar to less than 20% of the respondents. Jeruk kunci/ kesturi (*C. amblycarpa*) and bebuas (*Premna serratifolia*) are some examples for such less known species.

Relying on the ethnobotanical knowledge of the Tamiang tribe, the spice and condiment plants were divided into four categories, i.e. flavoring, seasoning, coloring, and preservation. Flavoring was the most important category among all communities followed by seasoning, preservation, and coloring (Table 3).

Of the total of 31 species recorded, some were used in more than one of the categories used. Accordingly, the Tamiang tribe used 31 plant species in flavoring, 26 species for seasoning, 3 species for preservation, and 2 species for coloring. This study in line with reported by Bharali et al. (2017) that flavoring was the most important category among all communities of Assam. In this study, several species have been identified which are used for various purposes. For example, the fruits of *A. moluccanus* are used both for flavoring and seasoning. However, the categories of use of a species may be different across sub-districts. *A. moluccanus* fruit is generally used for flavoring in Bendahara and Rantau, while this plant is used as condiments by local communities in the Seruway sub-district. This difference can be triggered by the assumption that individuals may have different interests, perceptions, and knowledge of plants. The frequency of the use of a plant species has been reported to depend on the way people live in contexts of their social and cultural (Shrestha and Dhillion 2006; Kumar et al. 2014).

The fruits (36%) were the most used as spice and condiment, followed by leaves (16%), seed (13%), rhizome and flower (10% each), bulb (6%), and stem and bark (3% each). The use of leaves as spices is similar reported in Sikkim, Manipur and Tripura, and Arunachal Pradesh (Gudade et al. 2015; Salam and Jamir 2016; Chakraborty and Chaturvedi 2015; Bharali et al. 2017). The leaves were mainly used for flavoring and seasoning which may be due to the presence of active secondary metabolites than other parts of the plants (Hidayati et al. 2017; Ismail and Ahmad 2019). Tamiang tribe use of *Alpinia galanga*, *Curcuma longa*, *Zingiber officinale* as spices. *C. longa* besides being a natural coloring in cooking can also give a distinctive flavor to the cuisine, while *Z. officinale* is also used to treat coughs. Most of the *Zingiberaceae* family is useful as a cooking spice, medicines, spices, ornamental plants, cosmetics, and drinks (Sarangnga et al. 2013).

Cocos nucifera the most widely used by Tamiang tribe in making traditional cuisines such as *bubur pedas*, *anyang*, and *ikan cang rebong*. The processing method is shredded pulp to be processed into coconut, relaxed, and ground coconut. In addition, *Capsicum annum* and *C. frutescens* are used to provide natural color and spicy taste of food. *Allium cepa* and *A. sativum* are usually processed by being ground up to a fine or thinly sliced then mixed with other spices such as *Aleurites moluccanus* and *Anethum graveolens*. However, *A. sativum* reported being used by local communities in Niger Delta, Nigeria as a seasoning and flavoring agent for the treatment of fever and chills (Ndukwu and Ben-Nwadibia 2005).

Table 2. List of the spices and condiments plants and their utilization in the study area

Scientific name	Family	Vernacular Name	Part used	Habit	Used	FI (%)
Aleurites moluccanus (L.) Willd.	Euphorbiaceae	Kemiri	Fruit	Tree	Spices and condiment	63,3
Allium cepa L	Amaryllidaceae	Bawang mirah	Bulb	Herb	Spices and condiment	100
Allium sativum L	Amaryllidaceae	Bawang puteh	Bulb	Herb	Spices and condiment	100
Alpinia galanga (L.) Willd.	Zingiberaceae	Lengkues	Rhizome	Herb	Spices	52
Amomum uliginosum J.Koenig	Zingiberaceae	Kapulage	Fruit	Herb	Spices	59,33
Anethum graveolens L	Apiaceae	Adas	Seed	Herb	Spices	50,67
Averrhoa bilimbi L	Oxalidaceae	Asam belimbing, Asam sunti	Fruit	Tree	Spices	84
Capsicum annuum L	Solanaceae	Cabe mirah	Fruit	Herb	Spices and condiment	100
Capsicum frutescens L	Solanaceae	Cabe kecik	Fruit	Herb	Spices and condiment	96
Cinnamomum burmannii (Nees & T.Nees) Blume	Lauraceae	Kayu manih	Bark	Tree	Spices and condiment	39,33
Citrus amblycarpa (Hassk.) Ochse	Rutaceae	Jeruk kunci/kesturi	Fruit	Tree	Spices	18,67
Citrus aurantifolia (Christm.) Swingle	Rutaceae	Jeruk nipis	Fruit	Tree	Spices	43,33
Citrus hystrix DC	Rutaceae	Jeruk purut	Fruit, leaves	Tree	Spices	60,67
Cocos nucifera L	Arecaceae	Kelambe	Fruit	Tree	condiment	68
Coriandrum sativum L	Apiaceae	Awas	Seed	Herb	Spices and condiment	54,67
Cuminum cyminum L	Apiaceae	Jintan	Fruit	Herb	Spices and condiment	48,67
Curcuma longa L	Zingiberaceae	Kunyik	Rhizome, leaves	Herb	Spices and condiment	98
Cymbopogon citratus (DC.) Stapf	Poaceae	Sere dapur	Stem	Herb	Spices	88
Etlingera elatior (Jack) R.M.Sm.	Zingiberaceae	Kecombrang	Flower	Herb	Spices	35,33
Garcinia atroviridis Griffith et Anders.	Clusiaceae	Asam gelugur	Fruit	Tree	Spices	55,33
Illicium verum Hook.f.	Schisandraceae	Pekak	Flower	Tree	Spices	50,67
Murraya koenigii (L.) Spreng.	Rutaceae	Daun kare	Leaves	Tree	Spices	98,67
Myristica fragrans Houtt.	Myristicaceae	Pale	Seed	Tree	Spices	37,33
Ocimum × africanum Lour.	Lamiaceae	Kemangi	Leaves	Herb	Spices	27,33
Paederia foetida L	Rubiaceae	Kentutan	Leaves	Climber	Spices	24,67
Piper nigrum L	Piperaceae	Lade	Seed	Climber	Spices and condiment	92,67
Premna serratifolia L	Lamiaceae	Bebuas	Leaves	Tree	Spices	19,33
Syzygium aromaticum (L.) Merr. & L.M.Perry	Myrtaceae	Cengkeh	Flower	Tree	Spices	36
Syzygium polyanthum (Wight) Walp.	Myrtaceae	Salam	Leaves	Tree	Spices	86
Tamarindus indica L	Fabaceae	Asam jawe	Fruit	Tree	Spices	68
Zingiber officinale Roscoe	Zingiberaceae	Halie	Rhizome	Herb	Spices and condiment	90

Tabel 3. Category of spices and condiment plants

Category	Species
Flavoring	*Aleurites moluccanus, Allium cepa, A. sativum, Alpinia galanga, Amomum uliginosum, Anethum graveolens, Averrhoa bilimbi, Capsicum annuum, C. frutescens, Cinnamomum burmannii, Citrus amblycarpa, C. aurantifolia, C. hystrix, Cocos nucifera, Coriandrum sativum, Cuminum cyminum, Curcuma longa, Cymbopogon citratus, Etlingera elatior, Garcinia xanthochymus, Illicium verum, Murraya koenigii, Myristica fragrans, Ocimum × africanum, Paedera foetida, Piper nigrum, Premna serratifolia, Syzygium aromaticum, S. polyanthum, Tamarindus indica, Zingiber officinale*
Seasoning	*Aleurites moluccanus, Allium cepa, A. sativum, Alpinia galanga, Amomum uliginosum, Anethum graveolens, Capsicum annuum, C. frutescens, Cinnamomum burmannii, Citrus amblycarpa, C. aurantifolia, C. Hystrix, Coriandrum sativum, Cuminum cyminum, Curcuma longa, Cymbopogon citratus, Garcinia xanthochymus, Illicium verum, Murraya koenigii, Myristica fragrans, Ocimum × africanum, Piper nigrum, Syzygium aromaticum, S. polyanthum, Tamarindus indica, Zingiber officinale*
Colouring	*Capsicum annuum, Curcuma longa*
Preservation	*Averrhoa bilimbi, Garcinia xanthochymus, Tamarindus indica*

Table 4. Trade of spice and condiment plants

Scientific name	Trade part	Number of respondents	Marketing	
			Mean quantity marketed per respondent (kg)	Market price (IDR/kg)
Allium cepa	Bulb	3	120 ± 1.25	50.000
Allium sativum	Bulb	2	80 ± 0.94	15.000
Alpinia galanga	Rhizome	3	8 ± 0.67	5.000
Averrhoa bilimbi	Fruit	1	20 ± 1.25	10.000
Capsicum annuum	Fruit	5	20 ± 0.94	20.000
Capsicum frutescens	Fruit	4	25 ± 2.36	50.000
Citrus aurantifolia	Fruit	2	7 ± 1.33	10.000
Citrus hystrix	Fruit	3	7 ± 1.33	30.000
	Leaves	3	2 ± 0.75	10.000
Cocos nucifera	Old fruit	50	200 ± 6.67	1.750
	Young fruit	50	100 ± 4.19	3.000
Curcuma longa	Rhizome	4	5 ± 0.94	5.000
	Leaves	4	1 ± 0.3	50.000
Cymbopogon citratus	Stem	6	8 ± 1.41	3.000
Garcinia atroviridis	Dried fruit	3	20 ± 2.31	6.000
	Wet fruit	3	300 ± 2.49	2.000

Several leaves of spices plants such as *Syzygium polyanthum* and *Citrus hystrix* are often used as a natural flavoring. These plants have essential oil content that provide a distinctive fragrance (Cahyadi 2006; Apriliani 2014). However, *Paedera foetida* and *Premna serratifolia* are very important condiments to making *bubur pedas*. These plants provide a distinctive taste and aroma. Spices that contain essential oils and are used by the community as natural flavorings are safe to use because they belong to the GRAS (Generally Recognized as Safe) group (Kim et al. 1995). *P. foetida* leaves also have benefits as a traditional medicine to treat digestive problems (Noprianti et al. 2018). *Averrhoa bilimbi*, *Tamarindus indica*, and *Garcinia xanthochymus* fruit can be used as a food additive for improving the aroma, taste, and food preservatives (Aqilah 2017).

The production and marketing of spice and condiment plants

Most of the respondents produced spices and condiment plants primarily for household consumption. Women and children were responsible for growing and selling the fresh produce of spices and condiment plants. Most of these plants are planting in the home garden. Approximately 57 % of the respondents have sold spices and condiment plants to increase household income. The widely produced home garden spices and condiments in the study area for both house consumption and sold in the local market were *A. galanga, A. bilimbi, C. longa,* and *G. atroviridis* (Table 4).

Most of the respondents sold spices and condiments to intermediary traders, some to consumers. The head of the household was responsible for selling spices and condiments in traditional markets. However, women usually sell small amounts of spices and condiment plants on the markets to meet basic needs, such as salt or eggs similar to the report of in South-West Ethiopia (Agize et al. 2013; Agize 2016) and in West Kalimantan (Robi et al. 2019). Generally, spices have been sold freshly, but several species have been dried, such as *G. atroviridis* before being sold, as is the case with the North Aceh people Indonesia (Navia et al. 2019b). The mean total annual contribution to the income of the household of the spices and condiment plants was around 38 %. From all respondents selling spices and condiment plants, 72 % were found to be earning annually less than 15,000,000 Indonesian Rupiah (IDR), 25 % earned between IDR 16.000,000 and IDR 30,000,000 while the remaining households earned more than IDR 30,000,000 but less than IDR 80,000,000.

Capsicum annuum were also commonly found in the study area as a similar report from in the Niger Delta Area of Nigeria (Ndukwu and Ben-Nwadibia 2005) and in Indonesia (Djarwaningsih 2005; Robi et al. 2019) and have high economic value. Indonesia was also one of the world's leading exporting countries in 2013, with the HS 904 group (Pepper, Chile, and *Capsicum*) among them (Hermawan 2015). This species widely consumed directly as vegetables or processed as spices in dried forms and also a primary ingredient in various hot sauces and pastes in different cuisines in Aceh Tamiang. The unique pungent flavor of *C. annuum* is due to the content of capsaicin and dihydrocapsaicin (Wang et al. 2009) which may increase appetite. The *C. annuum* was almost found in every home garden and the farmlands. Spices were sold separately or in various mixtures. Most of the traditional markets in Aceh Tamiang have been exceptionally well provided with indigenous and imported spices at all periods of the year.

Transfer of traditional knowledge among Tamiang Tribe

Culture plays a critical role in rural tribal livelihood, especially for the use of various spice and condiments plants (Bharali et al. 2017; Navia at al. 2019a). Each traditional cuisine has a special flavor that makes the taste of the cuisine unique. Seventeen species used for made *bubur pedas*, 5 species for *Anyang*, and 7 species for making *Ikan Cang Rebong*. However, *Ikan Cang Rebong* can be processed into two versions, namely *sayur lemak* and *pepes*. Traditional knowledge of the Tamiang tribe in the preparation and making of traditional cuisine has been passed down from generation to generation. Respondents from the study explained that knowledge of spices and condiments plants has been acquired mostly from parents and grandparents depicts that parents and grandparents account for 38% of knowledge, while 23% is mainly ancestors. Mothers always involve their daughters in the preparation and making of traditional cuisine. This study consistent with reported by Aqilah (2017) in Babah Dua Village, Aceh Jaya District, Aceh, Indonesia and in Kopen Dukuh Village, Banyuwangi District, East Java, Indonesia (Hakim et al. 2015). Van der Hoeven et al. (2013) reported elders to be the custodians of knowledge and transfer it to ensure it is not lost through generations. The study has recorded elders to be more knowledgeable about spices and condiment plants. In support of the study van der Hoeven et al. (2013) states that elders are the custodians of knowledge and they transfer their knowledge with such confidence so that it will not be lost through generations. Transfer of indigenous information within communities was mainly from parents to the younger generation (Ahmad and Pieroni 2016). The Tamiang tribe has always preserved traditional knowledge of the use of various spices and condiment plants for traditional cuisine.

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AJAB

Original Research Article

Pathogenic activity of *Fusarium equiseti* from plantation of citrus plants (*Citrus nobilis*) in the village Tegal Wangi, Jember Umbulsari, East Java, Indonesia

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Abstract

Some fungi associate with fruit and dead or dying plant tissues as pathogen on a wide range of agricultural plants. This work comprised the isolation, identification and pathogenic assay from citrus fruit plantations (*Citrus nobilis*), Tegal Wangi, Jember, Jawa Timur, Indonesia with 34 mold isolates obtained. Color of 7-day-old colonies cultures on PDA was dominated by white while the reverse was whitish to pale yellow. Based on the pathogenicity test, four representative mold isolates were identified as pathogenic fungi using the sequence of internal transcribed regions Spacer (ITS) in the region of ribosomal DNA selected. Molds were identified as UNJCC (D5) D5K3A (*Fusarium equiseti* with 98% homology bootstrap value 100%), UNJCC (D6) D6. K3.B (*F. equiseti* with 99% homology bootstrap value of 100%), and UNJCC (D7) D7.K2.B (*F. equiseti* with 99% homology bootstrap value 66%) and UNJCC (D8) D3.K2.B (*F. equiseti* with 99% homology bootstrap value of 55%). *F. equiseti* is a main source of trichothecenes, zearalenone and other mycotoxins which can cause serious disease in humans and animals. Present information regarding the *Fusarium equiseti* damage to citrus leaves can be used help identify the occurrence of pathogenic fungi in citrus fruit plantations.

Keywords: *Citrus nobilis*, *Fusarium equiseti*, Pathogenicity, ITS rDNA region

Introduction

Orange is one of the main crop in the village of Tegal Wangi, Indonesia which can help improve the well-being of its citizens in terms of economic development. Constraints faced by the farmers is a decrease in quality of citrus caused by mold destroyer (Sangwanich, 2013). Many citrus plants around agricultural land had suffered damage of tree trunks as brownish, mongering, leaves and fruits having wrinkles with black spots around on their surface. Mold cause serious losses annually on citrus fruit (Ghuffar et al. 2017). *Aspergillus*, *Penicillium*, *Rhizopus*, *Fusarium*, *Alternaria* and *Mucor* species are major disease source in citrus (Akhtar et al., 2013). Semangun (2007) reported *Fusarium* and *Aspergillus* in citrus fruits. Moscoso-Ramirez et al. (2013) reported mold *Penicillium digitatum* which resulted in whole green fruit and damaged stem with rotten fruit harmful to human health (Sangwanich et al., 2013; Sperandio et al., 2015. Plant diseases are of interest due to wide range of pathogens present in the rhizosphere especially fungi such as *Colletotrichum* sp. (Than et al. 2008; Cannon et al. 2012), *Fusarium* spp. (Tewoldemedhin et al. 2011), *Fusarium culmorum, F. Oxysporum, F. Sporo-trichioides, Alternaria alternata, A. tenuissima, A. arborescens, A. Infectoria* (Lee et al. 2005), *Alternaria* spp. (Serdani et al. 2002).

Apple trees are susceptible to wide variety of pathogens such as *Fusarium equiseti* (Alonso et al., 2015). Johnston (2008) isolated and identified a wide range of *Penicillium* molds from *Litchi chinensis* Sonn in South Africa using rDNA ITS regions. Wani (2011) reported *Colletotrichum coccodes, C. dermatum,* and *C. gleosporoides* cusing anthracnose in tomato fruits. Damage inflicted blackish-colored black wounds with concave pink colored mycelium growing (Rodrigues and Menezes 2005; Merr et al., 2013). Thiyam and Sharma (2013) showed fungal diseases from local fruits containing *Aspergillus, Acremonium, Alternaria, Aspergillus, Chalaropsis, Cladosporium, Curvularia, Fusariumm, Mucor, Penicillium, Rhizopus* and *Trichoderma* in all fruits during storage. In rainy season, the loss of production in infected fruits by molds can reach 100% (Arauz, 2000). Mold attacking citrus has become one of the limiting production factor in world citrus production (Timmer et al., 2000; Poppe et al., 2003). Fungi a universal pathogen that causes diseases on many fruits such as mango, papaya, and apple and especially in wither caused on citrus due to this pathogen. In this study isolation, identification and testing of highly pathogenic mold of citrus plantation of Siam in The Tegal Wangi Village, the control efficiency of yeasts isolate against pathogenic fungi from citrus leaves was investigated.

Materials and Methods

Sampling location

Location of the sampling site was Desa Krangkongan, Village Tegal Sari, Jember Umbul Wangi, East Java, Indonesia (Fig. 1). Samples were collected from seven citrus trees located in the four corners and center of the total area from orchards (Bagyaraj and Rangaswami, 2007).

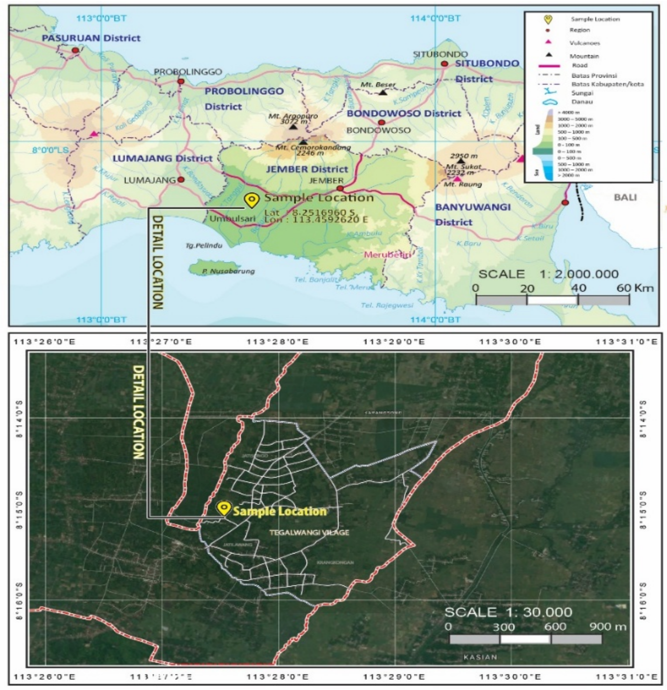

Fig. – 1: Sampling location

Isolation of fungi

For isolation of fungi from citrus plants, the agar method was applied. Fungal pathogens responsible for disease were isolated from leaf surface collected from sampled trees. From the samples obtained, serial dilutions (1:10) were prepared in test tubes with 9 ml sterile water, adding 1 g of leaf samples (previously sieved) until dilutions 10^{-5}, 10^{-6} and 10^{-7}, of which 50 μL and shaked at 200 rpm for 3 hours. Samples collected were seeded by duplicate through diffusion technique on Petri dishes of 90 mm diameter containing one of the following artificial Potato Dextrose Aga (PDA) and Czapecks agar medium. After incubation (25°C for 7 days) the number for each fungi was calculated. All fungi were cultured using a single spore technique on PDA and Czapecks medium. After incubation, fungi were identified by their macroscopic characters such as colony color, pigment production and mycelium characteristics, and through their microscopic characteristics like the presence of spores and arrangement of sporulation structures examined with a compound microscope (Carl Zeiss) at 1000X. All fungi were subcultured on PDA medium and stored at 4°C. Other isolation methods were also performed based on Farrag (2011) with modifications. Isolation was performed with mold using agar on infected leaves. We used a modified dental needle to the hilt. Each piece of medium was incubated on PDA medium at room temperature (± 30°C).

Purification of Pathogens

Pathogen fungal cultures obtained were purified by the single spore isolation method (Choi et al. 1999). Pure cultures were maintained on PDA slants for further study and preserved with L-drying method in the

University Negeri Jakarta Culture Collection (UNJCC).

Identification of macroscopic and microscopic fungi

Fungal cultures identification was based on macroscopic characteristics like colony morphology, color, texture, shape and appearance and microscopic characteristics like conidia shape, hyphe color, concentric zone, and pigmentation (Navi et al. 1999).

Pathogenicity test

Pathogenicity test used the agar smear method based on the principle of Koch's postulates. Parameter in testing was based on the measurement of disease incidence and severity using the formula described earlier (Embaby et al., 2013). Stages of the pathogenic test included sterilization of leaf surface and inoculation the pathogenic fungi on leaves. Leaf surface sterilization was performed by washing citrus leaves using sterilized water then soaked in a solution of sodium hypochlorite (NaOCl) 0.5% for one minute and further soaked in 70% alcohol for one minute before rinsing with sterilized water. Inoculation of the pathogenic fungi was done with an agar smear method based on Chutia et al. (2009)**.** Test fungi were inoculated with 5mm mycelium plugs from 7-days-old cultures and observation was for 10 days at a temperature of 25-27^{o}C. Growth of fungal species was recorded after one week of incubation and the percentage inhibition was computed after comparison with the control. Lime leaves were placed with 99% moisture and placed in the plastic tubs containing fruits before incubation. Observation was recorded after 10 days when kept at 25-27^{o}C (Agrios, 2005).

Identification of fungi using rDNA sequence

Identification of pathogenic fungi was done using the rDNA on ITS region described by White et al. (1990). Reaction mixture contained specific primers for ITS (Internal Transcribed Spacer region) rDNA region with primer ITS4 (5’-TCCTCCGCTTATTGATATGC-3’) and primer ITS5 (5’-GGAAGTAAAAGTCGTAACAAGG-3’). PCR reaction using PuReTaq™ Ready-To-Go™ PCR Beads (GE Healthcare) total reaction 25 µL, each reaction contained: 15 µL nuclease free water (NFW) dilution in PuReTaq™ Ready-To-Go (RTG) PCR beads (GE Healthcare), 10 pmol primer ITS4 and ITS5 (100 ng DNA template). PCR condition: denaturation at 95°C for 2 min (1 cycle); post denaturation at 94°C for 15 sec, annealing at 56°C for 30 sec, extension at 68°C for 1 min (40 cycles); and 70°C for 10 min in final extension (1 cycle) (Sukmawati et al. 2015). All PCR results were visualized using UV transilluminator after electrophoresis through a 1% agarose gel and ethidium bromide staining. PCR products were sent to 1stBASE (Malaysia) for sequencing.

Phylogenetic analysis

Nucleotide sequence datasets were automatically aligned using the MUSCULE program. Multiple alignments were carried out in MEGA6 (Molecular Evolutionary Genetics Analysis Version 6.0) (Tamura et al. 2007) and sequences retrieved from NCBI (http://www.ncbi.nlm.nih.gov). Phylogenetic analysis was conducted using the maximum likelihood (ML) method in MEGA6. ML analysis was tested by bootstrap (BS) analysis using 1000 replications. BS values of 50% or higher were shown and NR 130661 *Candida orthopsilosis* ATCC 96139 were used as outgroups.

Result and Discussion

Isolation of fungi

Physically observation of citrus fruits showed light brown color with bark peeling and brittle. Plant leaves were developing mold pathogen with blackish leaf spots blackish, speckled blotch, freckle spot, hard spot (shot-hole spot), yellowish, blackish sooty mold developed on the leaves or fruit fouled. Leaves turned yellowish but larger veins remained slightly green which easily fell (Fig. 2). Citrus spp. often got affected by fungal pathogens causing heavy fruit losses (Stammler et al. 2013). General symptoms of citrus plant infected by pathogenic fungi included leaf spots and chlorosis (Teixeira et al. 2005). Five plant pathogenic fungi such as *Alternaria alternata*, *Rhizoctonia solani*, *Curvularia lunata*, *Fusarium oxysporum* and *Helminthosporium oryzae* can infect citrus with black spots on infected leaves (Chutia et al., 2009). Plant pathogen included *Zygomycetes*, *Ascomycetes* and *Basidiomycetes* (Sukmawati, 2016; Teixeira et al. 2005). Fungi need nutrient from plant for their metabolism.

A total of 34 fungal isolates from citrus leaves was obtained showed diverse morphology of molds on stems and leaves. Mold isolates from the leaves were white (38.2%); light ochre-flesh (26.5%); flesh (8.8%); ochre (5.9%) and others (20.6%) (Table 1).

Mold isolated from leaves had sporulation and pigments (Sukmawati, 2016). Citrus is affected by several mold colors like green affecting fruit quality responsible for major postharvest problems like market losses. Their colors helped in preliminary identification like green and blue mold infections were caused by *Penicillium* spp. (Akhtar et al. 2013) and brown by *Colletotrichum gloeosporioides* Penz (Chung et al. 2002)

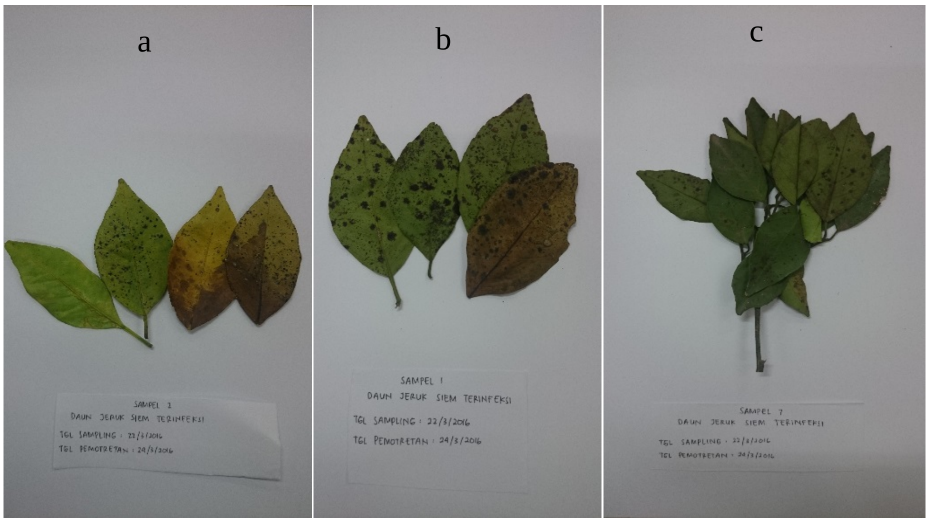

Fig. – 2: Citrus leaves infected with pathogen fungi a: leaves from first plant; b: leaves from second plant and c: leaves from third plant

Table – 1: Morphology of molds isolates on Potato Dextrose Agar (PDA), 3 days' incubation at 27--28^{0}C.

No.	Morphology colony of molds					
	Code of isolate (UNJCC)	**Colours**	**Margin**	**Sporulation**	**Reverse of colony**	**Diameter (L/W) cm**
1	D2. K1. B	White	White	Olive Green	Light Flesh	19.29 / 19.24
2	D3.K2. B	White	White	-	Cinnamon	25.97 / 23.72
3	D4. K1. A	White	White	Olive Green	Cinnamon	26.78 / 30. 46
4	D4. K1. B	White	White	Olive Green	Burnt ochre	22.33 / 26.84
5	D5. K1. A	White	White	Cinnamon	Ochre	31.06 / 32.70
6	D6. K3	white	White	-	light flesh	26.06 / 24.84
7	D7.K2. A	White	White	Cedar Green	white	28.15 / 28.32
8	D7.K2. B	White	White	-	Light Flesh	26.25 / 27.54
9	D7. K3	White	White	-	Light Ochre	77.69/60.30
10	D8. SP. K1. B	White	White	Grey green	White	37.44 / 39.29
11	D8.SP.K2. A	White	White	-	White	27.69 / 25.60
12	D8.SP.K2. B	White	White	Cedar green	White	46.66 / 52.96
13	D8. K1	White	White	-	Cream	82.68/45.00
14	D1. K3	Light Ochre	Light Ochre	-	Gold Ochre	42.25 / 62.77
15	D2. K1. A	Light Ochre	Warm Grey I	Cedar Green	Cinnamon	18.74 / 20.32
16	D3. K1	Light ochre	White	-	Light Ochre	72.84 / 82.36
17	D2. K2	Light Flesh	Cinnamon	-	Light Ochre	62.85/55.00
18	D5. K1. B	Light Flesh	White	-	Light Ochre	31.21 / 29. 78

19	D5. K2	Light flesh	White	Olive Green	Cinnamon	37.35 / 46. 86
20	D7. K1	Light Flesh	White	-	Light Ochre	81.62/46.00
21	D8.K2. A	Light Flesh	White	Light ochre	Ochre	45.47 / 79.17
22	D8.K2. B	Light Flesh	White	Ivory	Light Ochre	46.43 / 81.84
23	D6. K1. A	Medium flesh	Dark flesh	Juniper Green	Light Flesh	46.99 / 76.46
24	D6. K1. B	Medium flesh	Dark flesh	-	Ochre	39.59 / 60.07
25	D6. K2	Medium flesh	Light flesh	-	Light ochre	42.45 / 72.42
26	D3. K3	Ochre	Light Ochre	-	Gold ochre	44.07 / 75.75
27	D8. K3	Ochre	White	-	Gold Ochre	82.5/45.67
28	D1. K1. A	Cinnamon	Cold grey I	-	Light Flesh	21.45 / 21.26
29	D1. K1. B	Caput Mortum	Silver	-	Cold Grey II	18.09 / 19.42
30	D1.K2. A	Burnt Ochre	Brown Ochre	Warm Grey II	Raw Umber	51.81 / 58.22
31	D2. K3	Dark Flesh	White	-	Light Flesh	27.06 / 25.92
32	D3.K2. A	Gold ochre	White	-	Cinnamon	26.54 / 24.64
33	D5. K3	Cedar green	White	-	Olive green	27.96 / 18.74
34	D8.SP. K1.A	Olive green	White	Soft black	Juniper green	55.33 / 65.60

Mold isolated from citrus leaves showed 14 isolates (42%) with color variations among others; green, brown, and black (Table 1). Leaf is one of the source of nutrients and living place of mold isolates. Molds of citrus plants had been characterized by the colony with sporulation such as black, brown, green and yellow greenish (Chutia et al. 2009; Mohammed et al. 2013; Nasiru et al. 2015). Spores are asexual structures in the mold which is useful in deployments to the host (Akhtar et al. 2013; Sperandio et al. 2015). Mold pathogen had various colors like white, light, dark fleash, medium flesh ochre ivory, gold, cadmium and Hyalin (Akhtar et al. 2013; Chutia et al. 2009; Mohammed et al. 2013; Nasiru et al. 2015).

Pathogenicity test

Selection of 8 representative isolates was based on ability of sporulation. The representative mold consisted UNJCC (D1) D8.SP.K1.B; UNJCC (D2) D5. K1. A; UNJCC (D3) D4.K1.B; UNJCC (D4) D8.SP.K1.A; UNJCC (D5) D5.K3.A; UNJCC (D6) D6.K3.B ; UNJCC (D7) D7.K2.B; and UNJCC (D8) D3.K2.B. According to postulant Koch the pathogenicity test showed that four molds isolate were pathogenic (Table 2; Fig. 3). The value of the disease incidence and disease severity was indicated the highest by the isolate with code (D8) D3.K2. B (85%; 100%) (Fig. 3).

Test results proved that the four isolates with original mold causing damage in citrus leaves by highly pathogenic in accordance of Koch's postulates. According to Carla and Renata (2012), Koch's postulates can be used as a criterion of highly pathogenic isolates of a mold. The principle of Koch's postulates consists of: 1) Isolates can be isolated from the diseased host; 2) Isolates can be grown in the laboratory; 3) Isolate the results of isolation will give the same symptoms of the disease on the host, if re-inoculation; 4) Isolates will have the same morphology.

Table – 2: The pathogenicity test results 8 representatives of pathogen mold incubation 10 day at 30 ^{0}C

Isolate Code (UNJCC)	Characteristic of observation (day)				
	d0	d1	d3	d5	d10
(D1)D8. SP. K1. B	Green leaves	Green leaves	-	-	-
(D2)D5. K1. A	Green leaves	Green leaves	-	-	-
(D3) D4. K1. B	Green leaves	Green leaves	-	-	-
(D4) D8. SP. K1. A	Green leaves	There are several causes of brown spots	The color of the leaves becomes brown to black	The color of the leaves becomes brown to black	The color of the leaves becomes brown to black
(D5) D5. K3. A	Green leaves	There are several causes of brown spots	The tips of leaves first, but gradually the dark coloring	The tips of leaves first, but gradually the dark coloring	The tips of leaves first, but gradually the dark coloring
(D6)D6. K3. B	Green leaves	There are several causes of brown spots	The tips of leaves first, but gradually the dark coloring with growing mycelium = 7.28 mm	The tips of leaves gradually the dark coloring with growing mycelium = 8.45 mm	The leaves first, but gradually the dark coloring
(D7) D7.K2. B	Green leaves	There are several causes of brown spots	The leaves become brown to dark with growing mycelium length = 11.59 mm; width = 2.54 mm	The leaves become brown to dark with growing mycelium with white in the margin, with length = 13,61 mm; width = 3,83 mm	The leaves become brown to dark with growing mycelium with white in the margin, with length = 15.61 mm; width = 4,83 mm
(D8) D3.K2. B	Green leaves	There are several causes of brown spots	The leaves become brown to dark with growing mycelium length = 14.29 mm; width = 4.32 mm	The leaves become brown to dark with growing mycelium length = 15.72 mm; width = 4.39 mm	The leaves become brown to dark with growing mycelium length = 17.72 mm; width = 6.39 mm

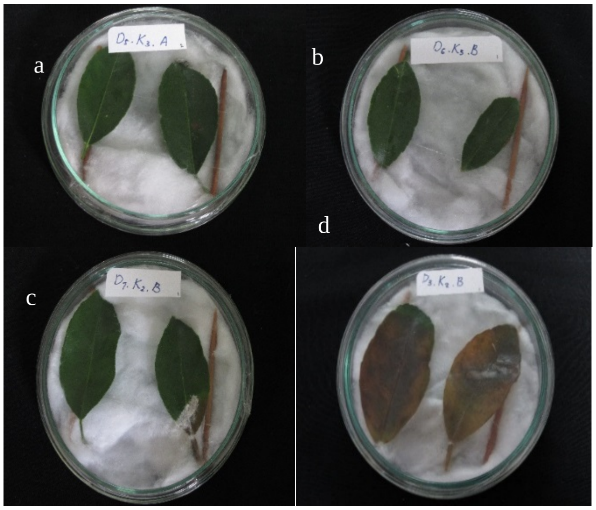

Fig. – 3: Pathogenicity test a: UNJCC (D5) D5.K3.A; b: UNJCC (D6) D6.K3.B ; c: UNJCC (D7) D7.K2.B and d: UNJCC (D8) D3.K2.B incubation 10 day.

Macroscopic observation and identification of molecular ITS region

Identification of molecular sequence analysis done using ITS rDNA region. PCR results on isolates obtained mold band with long bases 600 bp (Fig. 4).

Based on ITS regions of rDNA sequence data, four pathogenic isolates mold consisted following species as UNJCC (D5) D5K3A (*F. equiseti*) with similarity values 98%; UNJCC (D6) D6. K3. B (*F. equiseti*); UNJCC (D7) D7.K2.B (*F. equiseti*); and UNJCC (D8) (D3.K2.B) (*F. equiseti* and *F. oxysporum* sp. *fragariae*) with similar values 99%, which indicated high similarity to their closest species (Fig. 5, Table 4). Based on phylogenetic analysis, four isolates were found for *F. equiseti*.

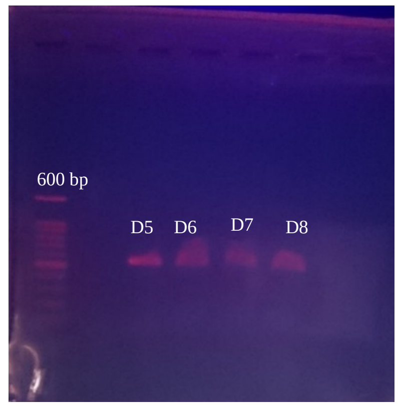

Fig. – 4: Electrophoresis results UNJCC (D5) D5.K3.A; UNJCC (D6) D6.K3.B ; UNJCC (D7) D7.K2.B and UNJCC (D8) D3.K2.B

Table – 3: Identification result of mold isolates from the leaves of citrus from Tegal Wangi Village based on ITS region of rDNA.

Isolate code (UNJCC)	Closely related species	Max scores	Total score	Query score	E-value	Similarity (%)	Accession number
(D5) D5K3A	*F. equiseti*	953	953	97%	0	98%	AY928409.
(D6) D6K3B	*F. equiseti*	1018	1018	99%	0	99%	KX588103.
(D7) D7K2.B	*F. equiseti*	987	987	98%	0	99%	KX588103.
(D8) D3.K2B	*F. equiseti*	1050	1050	99%	0	99%	KR364600.

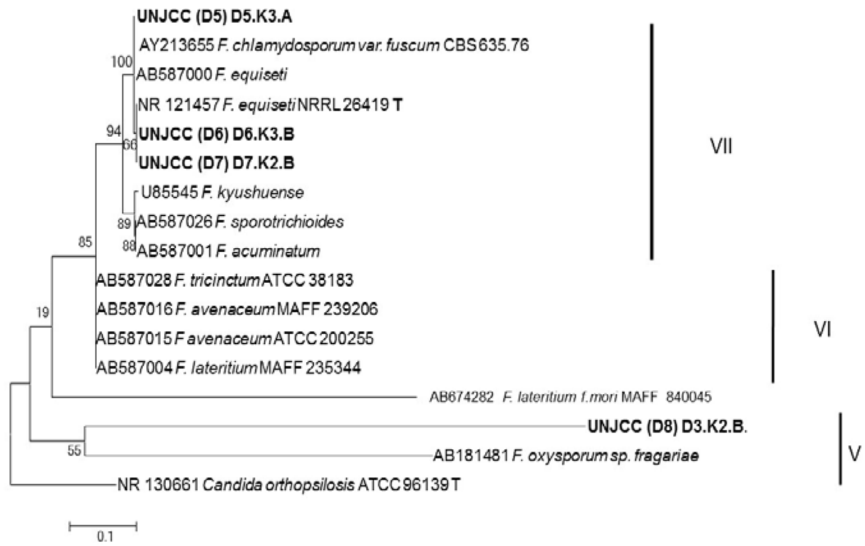

Fig. – 5: Maximum likelihood tree showing taxonomic position of *Fusarium* strains isolated from orange leaves: UNJCC (D5) D5.K3.A; UNJCC (D6) D6.K3.B; UNJCC (D7) D7.K2.B and UNJCC (D8) D3.K2.B. The tree was rooted to NR 130661 *Candida orthopsilosis* ATCC 96139

The *Fusarium* genome was first described by Link in 1809 (Aoki et al., 2014). Based on the phylogenetic tree, isolates (D5) D5.K3.A; (D6) D6.K3.B; (D7) D7.K2.B and (D8) D3.K2.B were identified as one clade with *F. equiseti* with bootstrap value of 94% (Fig. 5). The low value of the need for this data described the bootstrap analyzed by using a gene other than ITS rDNA. These regions have high success rates to identify a molecular approach (Schoch et al. 2012). But not all isolates of *Fusarium* can be identified are accurate based on a single gene. Isolate fungi with code (D8) D3.K2.B are identified as *F. equiseti*. While according to phylogenetic analysis isolate (D8) D3.K2.B was one clade with AB181481 *F. oxysporum* sp. *fragariae.* Watanabe et al. (2011) reported seven clade in *Fusarium.* Our riset consist of clade VII, clade VI and Clade V. Clade VI consists of *F. lateritium*, *F. avenaceum*, and *F. tricinctum*, which belong to different “sections”, namely, *Lateritium*, *Roseum*, and *Sporotrichiella* respectively. The paraphyly of *F. avenaceum and F. lateritium* was supported by all the genes. Clade VII contains 4 “sections” with 9 species: Eupionnotes consisting of *F. incarnatum*, *Gibbosum consisting of F. equiseti* and *F. acuminatum*, *F. graminearum and F. culmorum*, and *Sporotrichiella* consisting of *F. poae*, *F. kyusyuense*, *F. sporotrichioides*, and *F. langsethiae*. Clade V consisting *F. oxysporum sp. fragariae.* (Watanabe et al. 2011). *Fusarium* species is known one of the most difficult species to be identified based on morphological markers among fungal species. One of the main reasons for this difficulty is that genetic and morphological characters vary among strains in a species and the ranges of character diversity are often overlapped among closely-related species. Although all fore gene trees supported the classification of *Fusarium* species into 7 major clades, I to VII.

According to Tunarsih et al. (2015) suggested to use suitable marker for the identification of *Fusarium* members as *Fusarium* genome has possibly unique evolutionary history. Watanabe et al. (2011) used multigene analysis for *Fusarium* genome (18S rDNA gene, ITS1, 5.8S rDNA, 28S rDNA, β-tubulin gene, and aminoadipate reductase gene (*lys2*) for inter-species identification of *Fusarium*. Their results showed that sequence has homology with bootstrap value of 65–100%. *F. equiseti* mold can cause damage to various crops, including corn, rice and wheat in field and storage (Hasem et al. 2010). Palmero et al. (2011) reported that all the tested *Fusarium* isolates were pathogenic on tomato and melon. Regarding Bakar et al. (2013), *Fusarium* species are one of the common pathogens of post-harvest disease to cause rot on tomato and other perishable vegetable fruits. A total of 180 *Fusarium* isolates were obtained from 13 locations throughout Selangor. *Fusarium solani* was the most abundantly isolated (34%) followed by *F. semitectum* (31%) and *F. oxysporum* (31%), *F. subglutinans* (3%) while the last was *F. equiseti* (1%).

Fusarium equiseti is a plant pathogenic fungus and produce secondary metabolites form toxins that can be pathogenic on the various plants on agricultural land (Kosiak et al. 2005). Secondary metabolites produced vary in amount and toxicity. This species produces a variety of toxins, such as trichothecenes type A, for example, neosolaniol (NEO), diacetoxy-scirpenol (DAS), the type of T-2 toxin and HT-2, type B trichothecenes, for example, nivalenol (NIV), and non-essential compounds such as trichothecene zearalenon (ZEA), equisetin and fusarochromanone (Barros et al. 2012). In addition, it can also be profitable. This fungi have potential infection in rooting plants (Macia-Vicente et al. 2008) and the special nature of belonging so that could make these fungi as a candidate for biological control of nematodes (Nitao et al. 2001; Horinouchi et al. 2007). Other potential owned by mold, *F. equiseti* i.e. capable of producing the enzyme xyloglucanases (XG) (Rashmi & Siddalingamurty, 2016). These enzymes are known to have potential in processing waste plant, modifications to improve the nature of xyloglucans reologi in the food industry and the feed, fabric treatment to change the brightness and color, to remove the fuzz from the surface of textile materials in the textile industry and the paper industry (Sinitsyna, 2010). The enzyme is easily obtained so easily applied to help lower the cost of production.

Conclusion

Sampling mold pathogen in citrus plant plantation was done in isolation of pathogenic mold by direct and washing methods. Isolation retrieved as many as 34 isolates derived from leaf mold- Mold colonies from the leaves and stems were dominated by white colonists with mold. Testing of highly pathogenic samples was made from leaves of citrus plantation in Jember. Testing was conducted on eight isolates of highly pathogenic representative molds. Four potentials isolate mold caused the same damage when symptoms mold isolates from diseased leaves. These isolates were UNJCC (D5) D5. K3. A; UNJCC (D6) D6. K3. B; UNJCC (D7) D7. K2. B; and UNJCC (D8) D3. K2. B. Based on their phylogenetic analysis, all isolates were identified as *F. equiseti* (UNJCC (D5) D5K3A with 98% homology bootstrap values 64%, isolate UNJCC (D6) D6. K3. B 99% homology with bootstrap values 100%, isolate UNJCC (D7) D7. K2. B 99% homology with bootstrap values 99%, and UNJCC (D8) D8 D3. K2. B 99% homology with bootstrap values of 88%.

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AJAB
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Original Research Article

Spectroscopic and morphological characteristics of genus *Jatropha* (Euphorbiaceae) and genus *Jojoba* (Simmondsiaceae)

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Abstract

Using second generation of biofuel that does not affect food crop production is an issue of global concern. Remote sensing (RS) proved to be efficient technique for inventory and monitoring the spatial distribution of biofuel plants at both local and regional scales. It is used also for site selection of the most suitable sites for the plantation of these plants through the integration of multi spatial layers. Spectral identification of these plants and the relationship between spectral and morphological parameters were not observed.

This work is considered the first step of a series of studies deals with the identification of the spectroscopic parameters and their relation with morphological parameters of the most common Egyptian natural vegetation. At this stage, two sources of fossil oil plants Jatropha and Jojoba were investigated. Spectral reflectance was measured using ASD spectroradiometer device and the spectral signature was identified for the two taxa. Secondly, optimal spectral zone and wavelength/s were identified for each sample. A Strong relation was found between chlorophyll content and spectral reflectance at visible spectral region. Normalized difference vegetation index (NDVI) was found to be highly correlated with chlorophyll content. Further work will be carried out to quantitatively relate the amount of ingredient fossil oil of these plants with spectroscopic characteristics.

Keywords: *Jatropha*, *Jojoba*, Spectroscopic Characteristics, Morphological Characters

Introduction

World's energy demand is increasing significantly according to the development of the industrial economy and huge population growth. Fossil fuels are the source and motive for many economic and environmental crises including instability of fuel price, declining energy resources, rising air and land temperature that leads to climate change and global warming. Importance of biofuel is increasing significantly as the world is struggling to face the problems of global warming and shortage in energy sources that threaten sustainable development in many regions of the world. Increasing the usage of renewable energy will certainly reduce global warming. International Energy Agency (IEA) determined amount of produced biofuel globally by about 83 billion liters (Ndegwa and Geoffrey et al. 2011).

Researchers worldwide are working to extract liquid biofuels like biodiesel and ethanol. Generally, there are two types of biofuel; the first type depends on economically valuable food crops such as maize/corn, sugarcane, wheat, or others. This type of biofuel is inconsistent with the requirements of food security. The second type of biofuels does threaten food security since it depends on non-edible woody plants such as *Jatropha* that get strong attention since the beginning of the 21st century due to its rich non-edible oil content (around 35 to 48 percent) (Openshaw, 2000; Fei et al., 2005).

Jatropha is a genus of about (175) plants belong to family Euphorbiaceous. It is divided into two subgenera, *Jatropha* and curcas. Subgenus *Jatropha* occurs widely in Africa, India, South America, West Indies, Central America, and the Caribbean (Leal and Agra 2005). Hutchinson and Dalziel (1958) (Hutchinson and Dalziel 1958) identified eight species of *Jatropha* in West-Tropical Africa, while Ratha and Paramathma (2009) identified twelve species of *Jatropha* in India, using morphological traits. *Jojoba*, (*Simmondsia Chinensis* (Link) Schneider), belongs to the family Simmondsiaceae, is a new semi- arid oil industrial crop that recently has to get more attention.

Earlier botanists placed Jojoba in the family Buxaceae, based on anatomical studies of Buxaceae, while (Melikyan, 1968) placed Simmondsia in a separate monotypic family Simmondsiaciae. This supports the contention of Van Tieghem the Belgian botanist in 1898 who suggested on the basis of the dioecious breeding system, floral morphology, and wood anatomy that jojoba be put into the family of its own, Simmondsiaceaen (Anon, 1980) and this was later supported by (Scogin, and Brown, 1979; Sherbrook, 1976a) who reported that based on the international rules of botanical nomenclature, the only valid scientific name for jojoba is (*Simmondsia chinensis* (link) Schneider).

Jatropha genus includes many toxins including lectin, saponin, carcinogenic phorbol and a trypsin inhibitor. *Jatropha gossypifolia* is recognized as invasive and highly toxic to human when the oil of *Jatropha curcas* is a purgative ones that is toxic in large quantities (Smith, 1923).

Simmondsia Chinensis (link) Schneider) (Jojoba) is another shrub that is getting high attention because of its valuable ingredient of oil that is used as a source of energy and for cosmetic purposes. The two plant genus (*Jatropha* and *Jojoba*) are sources of biofuel as well as their importance in medical and cosmetic purposes.

The two plant genus (*Jatropha* and *JoJoba*) are resources of biofuel in addition to their importance in medical and cosmetic purposes. The two plant genus are dry tolerant and could be cultivated over large areas in an arid and semi-arid environment of Egypt with no negative effect on food security. Therefore, it has been suggested that they should be cultivated over large areas of low capability soil as there is no competition for land with food crops.

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Its ability to regularly monitor habitat and invasive species is critical for better understanding of ecosystem and climate models (Kerr, and Ostrovsky, 2003), however, ecological monitoring and modeling the dynamics of an ecosystem may require higher spectral, temporal and spatial resolutions remotely sensed data. Hyperspectral remotely sensed data improved both ecological and geologic analysis of the earth's surface because of its ability to identify and discriminate spectral reflectance patterns of mineralogy, soil, vegetation (Van der Meer, 1998; Kruse et al., 2003; Schmidt and Skidmore, 2003; Apan et al., 2004).

Hyperspectral (RS) was used to differentiate particular environmental variables that were impossible to be identified using multispectral, broadband imagery. (RS) was used to propose a method for site selection of Jatropha C. plantation (Arslan, et al., 2015). Identification of the spectroscopic parameters and spectral reflectance pattern of Jatropha and its correlation with morphological characteristics has not been searched before. Spectral reflectance characteristics of Jojoba under salinity stress were studied by (Rao, et al. 2000). It was found that reflectance in near infrared range decreases with increasing age and leaf area index (LAI).

The main objective of the current study is to use microscopic examinations of morphological characters to provide useful taxonomic data that give further insight into proper classification, delineation, and identification of the studied taxa. Another aim is to identify spectroscopic characteristics and spectral reflectance pattern for four species of *Jatropha* and *simmondsia chinensis* (link) Schneider). The study aims also to analyze the correlation between spectral reflectance pattern and morphological characteristics of the studied taxa. Furthermore, the study identifies the optimal wavelength region and the specific wavelength for each investigated sample. These optimal wavelengths could be correlated with the amount of ingredient oil and physiological conditions of the studied samples.

Materials and Methods

Experiment was performed for four species from *Jatropha* genus that are common in Egyptian environment: *Jatropha curcas* L., *Jatropha gossipifolia* L., *Jatropha integerrima* Jacq, *Jatropha multifida* L and *Simmondsia chinensis* (link) Schneider). Plant materials were collected during a field observation to Al Orman Garden from May 2016. Morphological features were described following Taxonomy of Flowering Plants (Grill, 1998).

Spectral reflectance of the different samples was measured by (FieldSpec 4 Hi-Res NG Spectroradiometer). The device measured radiance in over two thousands wavebands ranged from (0.3 – 2.5 micrometer). Radiance of white reference was saved in a sampling file that comprises ten radiance spectra. Two vegetation indices: hyperspectral normalized difference vegetation index (NDVI) and Chlorophyll index (CI) were calculated. Then, statistical analysis was performed in two main steps. Turkey's procedure was applied to define the optimal waveband region for each investigated sample. Linear discrimination analysis (LDA) was applied to identify the unique wavelength/s for each investigated taxa.

Results and Discussion

Morphological analysis

Morphological characteristics of the studied taxa are presented in table – 1. In order to facilitate deducing the most important diagnostic characters, it was found that habit shrub in *J. gosspifolia*, *J. integrima* and *Simmondsia chinensis* or shrub/small tree in *J. curcas* and *J. multifida*, or herb in the remaining studied taxa; Stem erect in *J. curcas, J. gossypifolia, J. integerrima* and *Simmondsia chinensis*, erect or somewhat succulent in *J. multifida* or branched in *Simmondsia chinensis* .

Petiole absent in *J. curcas, J. integerrima* and *Simmondsia chinensis;* petiole 3–14 cm long in *J. gossypifolia;* petiole 10–30 cm long *in J. multifida* or; Leaf composition simple in all taxa; Shape of blade broadly ovate in *J. curcas*, *J. multifida* and *gossypifolia,* obovate in *J. integerrima* or oblong in *Simmondsia chinensis*; Apex of blade acute or shortly acuminate tip in *J. curcas*, acute in *J. gossypifolia*, *J. multifida* and *Simmondsia chinensis*, acuminate in *J. integerrima*; Color of blade light green in *J. curcas*, Green in *J. gossypifolia* and *J. multifida*, dark green in *J. integerrima* and green to grey in *Simmondsia chinensis*; Margin of blade entire in *J. curcas*, *J. integerrima*, *J. multifida* and *Simmondsia chinensis* or Serrated in *J. gossypifolia*; Petiole detection petiolate in all taxa. This is in agreement with (Dehgan, and Webster, 1979; Dehgan, 2012; Ratha, and Paramathama 2009)**.**

Inflorescence position terminal in *J.curcas*, *J. multifida*, *J. gossypifolia* and *J. integerrima* or axillary in *Simmondsia chinensis*, Inflorescence type dichasial cymose in *J. curca*, Scorpioid raceme in *J. gossypifolia*, polychasial cymose in *J. multifida*, subcorymbiform in *J. integerrima* or cymose in *Simmondsia chinensis*; Number of flowers / inflorescence five in *J.curcas*, *J. multifida*, *gossypifolia* and *J. integerrima* or 2-7 in *Simmondsia chinensis*. This agreed with (Undersander, et al.. 1990).

Flower unisexual in all studied taxa; Flower color creme in *J.curcas*, red in *J. multifida*, *J. gossypifolia* and *J. integerrima* or greenish-yellow in *Simmondsia chinensis*; Cohesion of sepals polysepalous in *J.curcas*, *J. multifida*, *gossypifoli* and *Simmondsia chinensis* or gamosepalous in *J. integerrima*; Petal shape oblong-obovate in *J. curcas*; Broadly obovate to spade-like, c. 3.5 by 2 mm in *J. gossypifolia*, obovate, c. 5 by 2.5 mm in *J. multifida* or obovate, 10–13 by 4–5 mm in *J. integerrima*; Number of stamens 10, the 5 outer filaments only basally united, the 5 inner completely united in *J.curcas*, stamens 8, the 5 outer filaments united in the lower half, the 3 inner ones united for two-thirds in *J. gossypifolia*, 8, c. 5 mm long; The filaments quite free in *J. multifida* , 10, the 5 outer filaments united for three-quarters, the 5 inner ones unitd for two-thirds their length in *J. integerrima* or 10–12 stamens per flower in *Simmondsia chinensis*; Ovary position superior in all taxa under investigation; Stigma form elongate, erect, thickened, bifid in *J. curcas*, free, erect, capitate, bifid in *J. gossypifolia*, capitate, bilobed in *J. multifida*, deeply bifid in *J. integerrima* or papillate in *Simmondsia chinensis*. This agreed with Anon (2004). Fruit dehiscent in all taxa under investigation; Shape of fruit ellipsoid to tear drop shaped in *J. curcas*, Globose capsule in *J. gossypifolia*, Ellipsoid capsule in *J. multifida*, ellipsoid to ovoid in *J. integerrima* or capsule in *Simmondsia chinensis*. Seed size c. 1.7 by 1 cm in *J. curcas*, c. 7.5 by 4.5 mm in *J. gossypifolia*, 1.5–2 by c. 1.5 cm in *J. multifida*, c. 5 mm wide in *J. integerrima* or 1(-3)-seeded-0.5-1.1 g in *Simmondsia chinensis;* Seed Shape compressed ovoid-ellipsoid in

J. curcas, ovoid to ellipsoid-ovoid in *J. gossypifolia*, Broadly ovoid- ellipsoid to subglobose in *J. multifida*, Ellipsoid to ovoid, 8–9 in *J. integerrima*, ovate in shape in *Simmondsia chinensis*. This is in agreement with (Fairless, 2007; Buchmann, 1987).

Table – 1: Macromorphological Characters of the studied taxa.

Character	***J. curcas***	***J. gossypifolia***	***J. multifida***	***J. integerrima***	***Simmondsia chinensis***
Habit	Shrub/small tree	Shrubs up to 3 m tall	Shrubs or small trees, up to 7 m high	Shrub up to 6 m tall	Shrub
Stem	Erect	Erect	Erect somewhat succulent	Erect	Erect
Petiole					
Petiole	Absent	Petiole 3–14 cm long	Petiole 10–30 cm long	Absent	Absent
Leaf					
Leaf shape	Broadly ovate	Broadly ovate	Broadly ovate	Obovate	Opposite, oval in shape
Leaf colour	Light green	Green	Green	Dark green	Green to gray in color
Leaf apex	Acute or shortly acuminate tip	Acute	Acute	Acuminate to cuspidate	Acute
Form of margin	Entire	Serrated	Entire	Entire	Entire
Inflorescence					
Position	Terminal	Terminal	Terminal	Terminal or axillary	Axillary
Inflorescence type	Dichasial cymose	Scorpioid cymose	Polychasial cymose	Sub corymbiform	Raceme
No. of flowers	5	5	5	5	2-7
Penducle	Long and smooth ending	Long and smooth ending	Long and smooth ending	Glandular teeth	Long and smooth ending
Flower					
Color	Creme	Red	Red	Red	Greenish-yellow
Sex	Unisexual	Unisexual	Unisexual	Unisexual	Bisexual
Sepal	polysepalous	polysepalous	polysepalous	Gamosepalous	Polysepalous
Petal	polypetalous	polypetalous	polypetalous		
Petal shape	Oblong-obovate	Broadly obovate to spade-like, c. 3.5 by 2 mm	Obovate, c. 5 by 2.5 mm	Obovate, 10–13 by 4–5 mm	Without petals
Stamens	10, the 5 outer filaments only basally united, the 5 inner completely united	Stamens 8, the 5 outer filaments united in the lower half, the 3 inner ones united for two-thirds	8, c. 5 mm long, the filaments quite free	10, the 5 outer filaments united for three-quarters, the 5 inner ones united for two-thirds their length	10–12 stamens per flower
Ovary	Glabrous	Hirsute especially towards the apex	Trigonous	Glabrous	Glabrous
Position of ovary	Superior	Superior	Superior	Superior	Superior
Stigmas	Elongate, erect, thickened, bifid	Free, erect, capitate, bifid	Capitate, bilobed	Deeply bifid	Papillate

Fruit					
Fruit shape	Ellipsoid to tear drop shaped	Globose capsule	Ellipsoid capsule	ellipsoid to ovoid	Ovoid capsule
Dehiscence	Dehiscing loculicidal.	Dehiscing both septicidal and partly loculicidally	Dehiscent to sub drupaceous	Dehiscing	Dehiscent
Seeds					
Size	c. 1.7 by 1 cm	c. 7.5 by 4.5 mm	1.5–2 by c. 1.5 cm	c. 5 mm wide	1(-3)-seeded 0.5-1.1 g
Shape	Compressed ovoid-ellipsoid	ovoid to ellipsoid-ovoid	Broadly ovoid-ellipsoid to subglobose	Ellipsoid to ovoid, 8–9	Ovate in shape

Figure – 1: Macrophotographs of the studied taxa. A. *Jatropha curcas*, B. *Jatropha gossipifolia*, C. *Jatropha integerrima*, D. *Jatropha multifida*, E. *simmondsia chinensis*

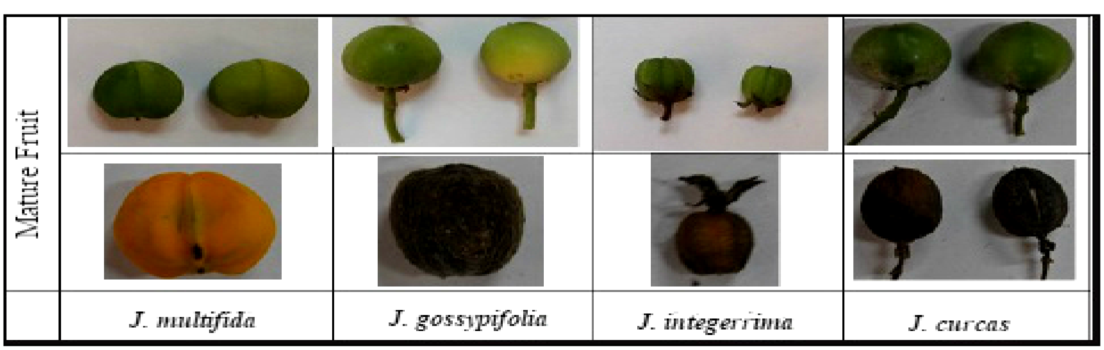

Figure – 2: Shape of fruits for four Jatropha species.

Spectroscopic characteristics

Spectral reflectance of plant leaves could be characterized as absorption centered at about 650 nm (visible red) by chlorophyll pigment in green-leaf chloroplasts in the outer of Palisade leaf, and to a similar extent in the blue, removes these spectrums from white ones, leaving the predominant reflectance for visible wavelengths concentrated in the green. Strong reflectance between (700 and 1000 nm) is from spongy cells in the interior or back of a leaf.

Spectral reflectance pattern of the investigated taxa as shown in figure (3) indicated the same trend of spectral reflectance as all samples are vegetative samples. The highest spectral reflectance was identified in near infrared spectral region; lower spectral reflectance was identified in shortwave infrared while the lowest spectral reflectance was identified in the visible spectral region (350 - 700 nm). The spectral Reflectance in SWIR1 was higher than the spectral reflectance in SWIRII with all samples. Relatively higher spectral reflectance was found for Jatropha gossypifolia and Simmondsia chinesis through the whole spectral regions, however, comparing with other plants, significantly higher spectral reflectance for the two plants over the rest of the plants was identified in the wavelength region from (350 - 700 nm).

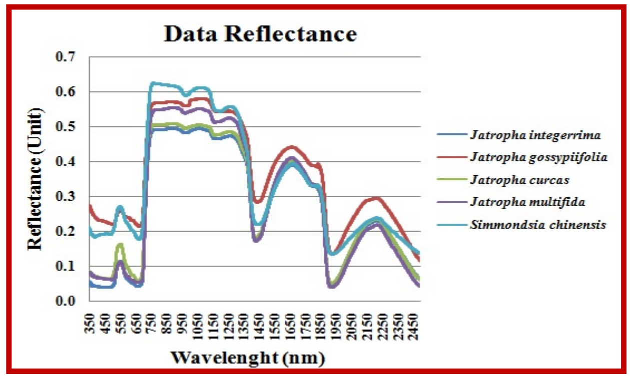

Figure – 3: The Spectral Reflectance Pattern for the Different Species

The result of Tukey's procedure as shown in figures (4, 5, 6, 7, 8 and 9) indicated that (SWIR-I) and (SWIR-II) were not sufficient for the spectral discrimination between samples. At the same time, NIR and blue spectral regions were the optimal to discriminate investigated taxa when green and red spectral regions showed acceptable results for discrimination.

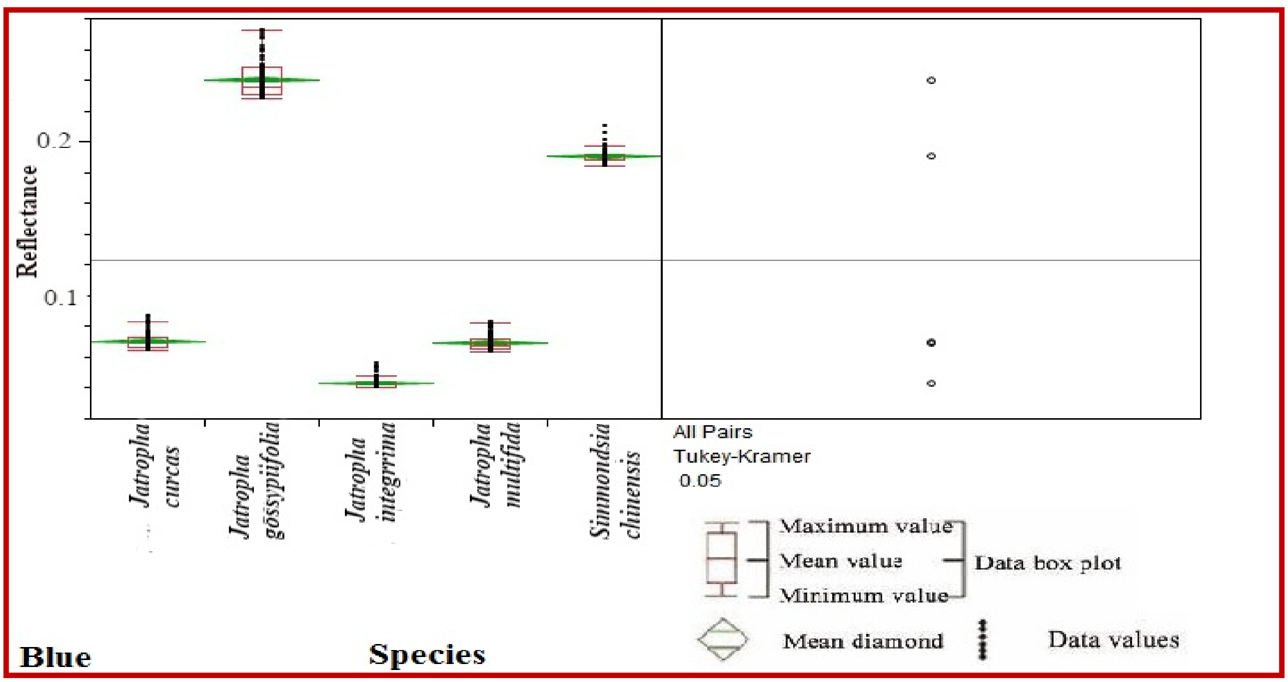

Figure – 4: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in blue spectral zone

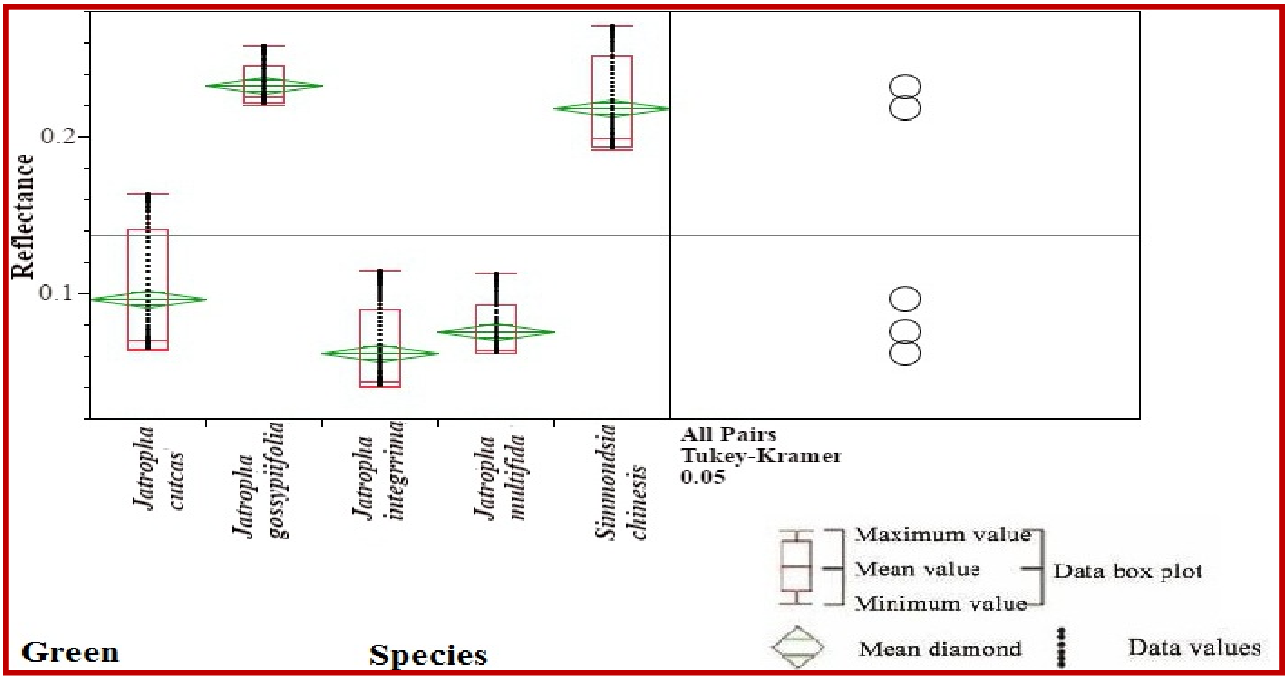

Figure – 5: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in green spectral zone

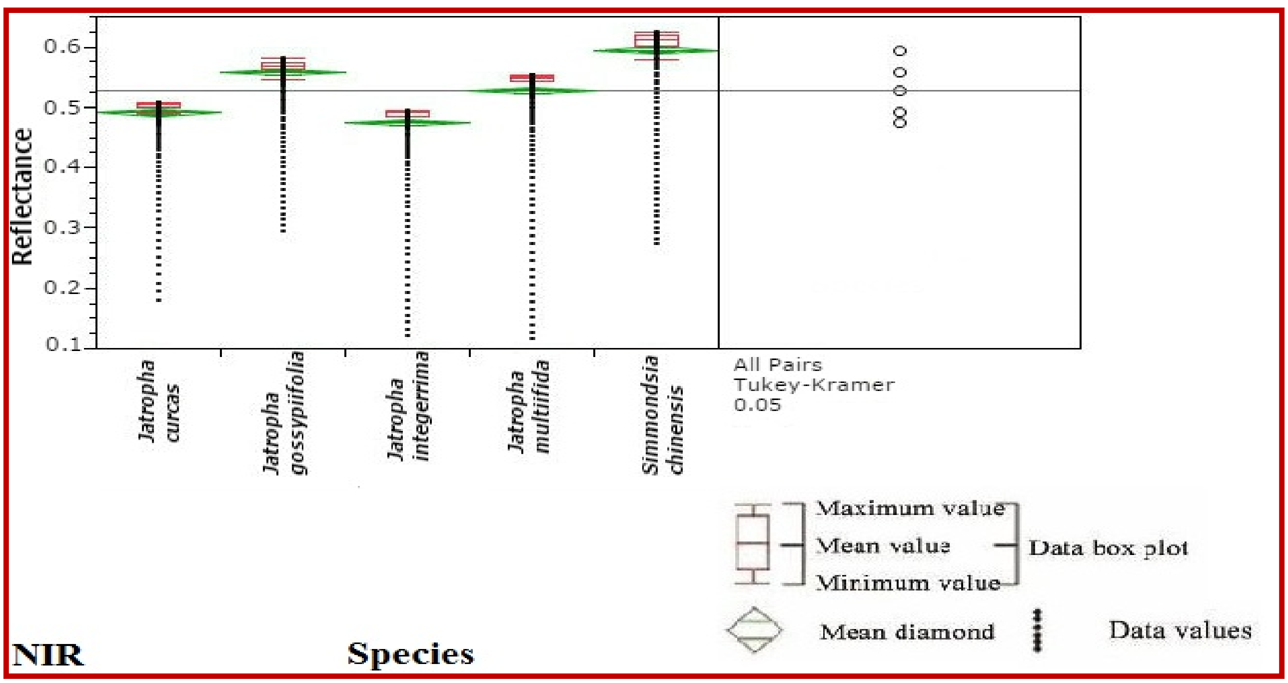

Figure – 6: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in red spectral zone

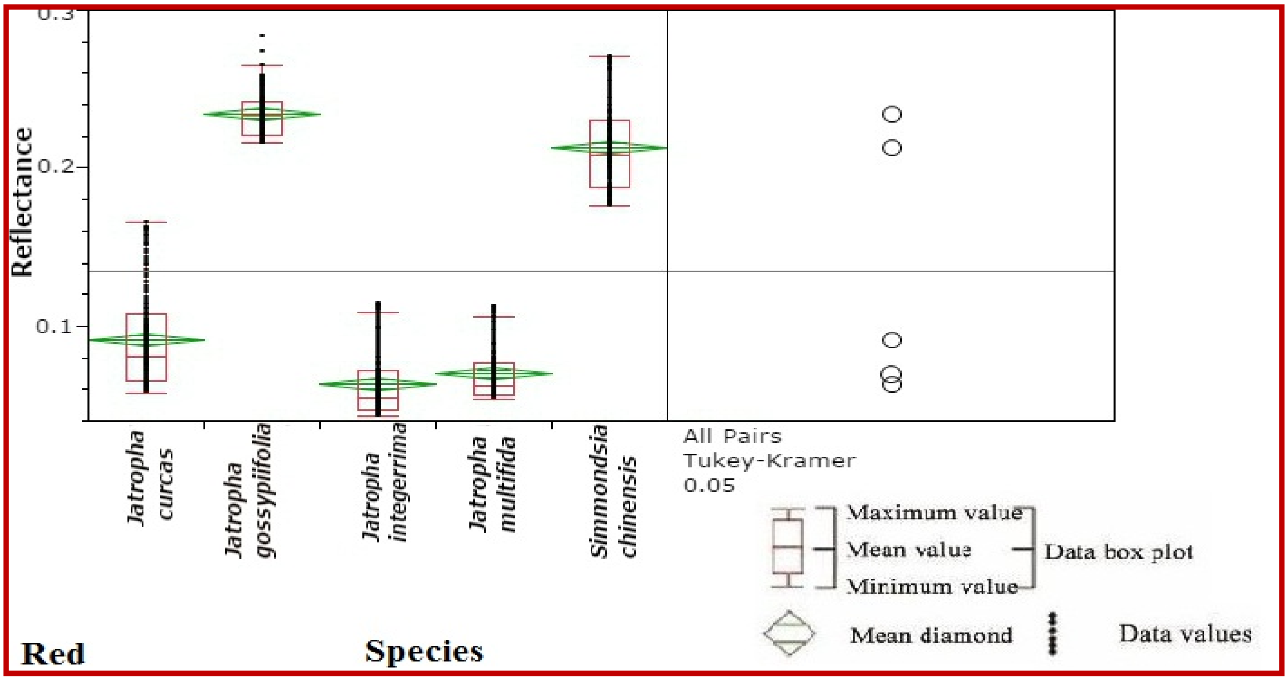

Figure – 7: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in near infrared (NIR) spectral zone

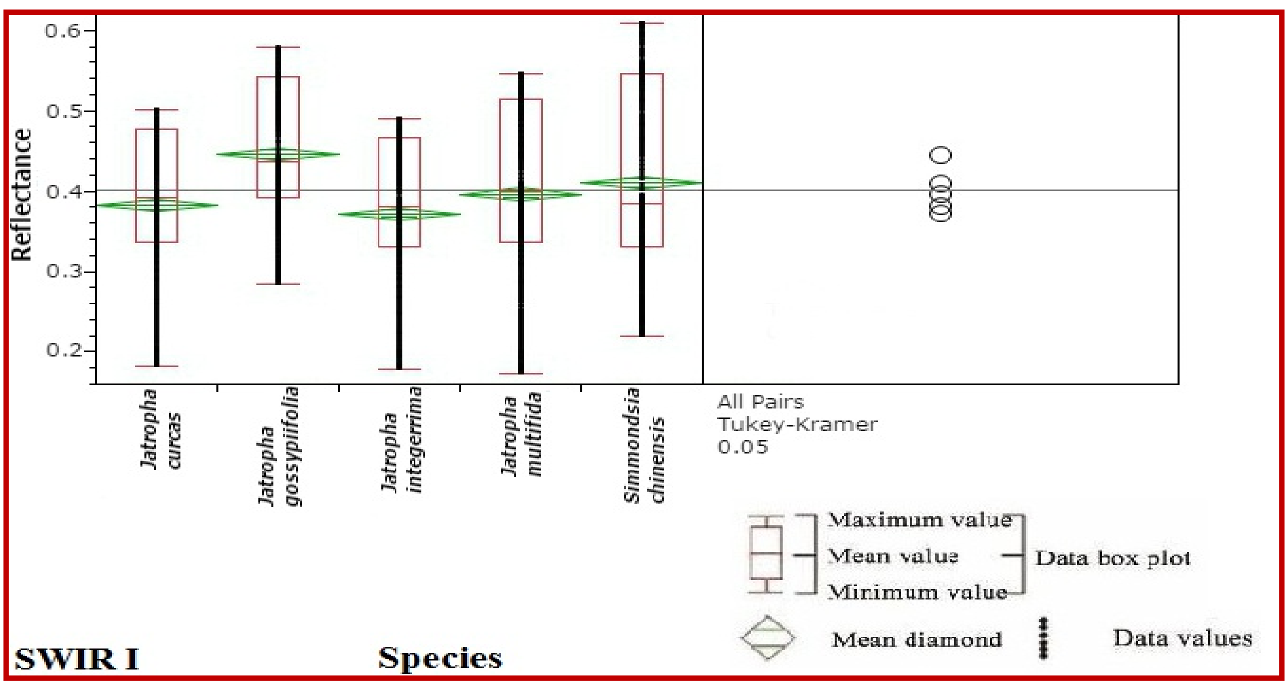

Figure – 8: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in SWIRI spectral zone

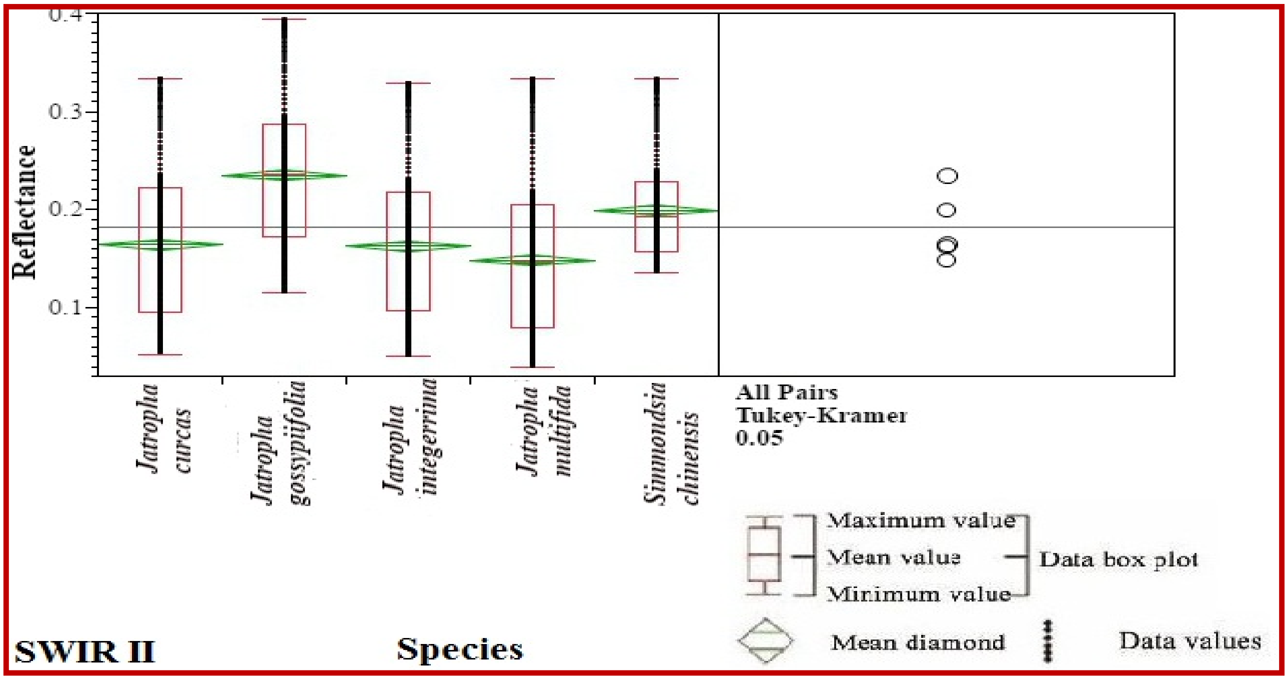

Figure – 9: ANOVA and Tukey's HSD analyses to discriminate the studied taxa in SWIRI spectral zone

The results of the the linear discriminate analysis are shown in the table (2). This analysis identified the specific wavelength for each taxon. Uniquely, visible spectral region (350 - 713 nm) and far SWIRII spectral region (1859 - 2500 nm) were the optimal to identify *Jatropha integerrima* although the value of spectral reflectance in the visible region was the lowest compared with reflectance values of the other taxa in the same spectral region. Since most of the visible light is used by chloroplastides for photosynthesis, the amount of reflectance is quite low and plant leaves appear in dark green color for morphological description and appear also in the value of chlorophyll index (0.43). *Jatropha gossypiifolia* and *Simmondsia chinensis* showed a higher spectral reflectance with all region, however, the unique spectral zone was different from one another. When *Jatropha gossypiifolia* showed one wide spectral range including NIR and SWIR-1, *Simmondsia chinensis* showed different narrow spectral zones for discrimination. The specific wavelengths for the rest of the samples were close to each other as an indicator for close anatomical characteristics.

Calculated values of (NDVI) and (CI) as shown in the table (3) indicated the close relation between chlorophyll and spectral reflectance of red and infrared spectral zones. High chlorophyll content in plant leaves leads to using most of the red spectrum in photosynthesis resulting in very low reflectance in the red spectral zone that is finally translated in high (NDVI). These results agree with morphological characteristics as the plants with the highest reflectance in red spectral zone appear in light green color when low red spectral reflectance appears in dark green color.

Table – 2: The Optimal waveband to identify different taxa

Species	Wavelength
Jatropha curcas	708, 1394, 1510, 1511, 1512, 1513, 1857, 1858
Jatropha gossypiifolia	708-1860
Jatropha integerrima	350-713, 1395-1515, 1859-2500
Jatropha multifida	714-716, 1390-1393, 1518-1534, 1844-1856
Simmondsia chinensis	706-709, 1388-1393, 1544-1582, 1751-1850

These results explain that spectroscopic parameters and spectral signature could be used for the identification of plant taxa as morphological and anatomical parameters. Further work is necessary for the establishment of the spectral library of the common natural vegetation in Egyptian environment.

Table – 3: NDVI and CI values

Plant	NDVI	CI
Jatropha curcas	0.124	0.068
Jatropha integerrima	0.986	0.580
Jatropha gossypiifolia	0.433	0.425
Jatropha multifida	0.112	0.006
Simmondsia chinensis	0.362	0.156

The water content of *Jatropha gossypiifolia* was less than the rest of the samples folled by *Simmondsia chinensis*. This appeared in high reflectance in SWIR spectral region for these two taxa.

Conclusions

This study is the first of series that observe the spectroscopic characteristics of the common economically valuable natural vegetation in Egyptian environment. The current study was carried out to identify spectroscopic characteristics of five taxa that have increasing importance as sources of fossil fuels. Observing the relationship between spectroscopic and morphological characteristics was among the objectives of this study. Morphological analysis of all samples was carried out and field spectral reflectance measurements were carried out using ASD field spectroradiometer device. The study identifies the spectral signature, the spectral zones and the specific wavelength/s for each taxon. Generally, *Jatropha gossypiifolia* and *Simmondsia chinensis* showed higher reflectance than the rest of the samples, when, *Jatropha integerrima* showed specific wavelength for identification. Morphological characteristics show a strong relation with both normalized difference vegetation index (NDVI) and chlorophyll index (CI). The study indicated that spectroscopic parameters and spectral signature could be used in parallel with morphological and anatomical characteristics for the identification and classification of plants. This study will be followed by other studies to quantitatively relate the content of fossil fuel of the pants with spectroscopic characteristics.

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