sustainability

MDPI

Article

Determination of the Allelopathic Potential of Cambodia's Medicinal Plants Using the Dish Pack Method

Yourk Sothearith [1,2,*], Kwame Sarpong Appiah [1], Hossein Mardani [1], Takashi Motobayashi [1,*], Suzuki Yoko [3], Khou Eang Hourt [4], Akifumi Sugiyama [5] and Yoshiharu Fujii [1,*]

[1] Department of International Environmental and Agricultural Science, Tokyo University of Agriculture and Technology, 3-5-8, Saiwai-cho, Fuchu, Tokyo 183-8509, Japan; ksappiah90@gmail.com (K.S.A.); hmardani26@yahoo.com (H.M.)

[2] Department of Biodiversity, Ministry of Environment, Morodok Techcho (Lot 503) Tonle Bassac, Chamkarmorn, Phnom Penh 12301, Cambodia

[3] Aromatic Repos, AHOLA, A2 Soleil Jiyugaoka, 1-21-3, Jiyugaoka, Meguro, Tokyo 152-0035, Japan; yoko86252539@gmail.com

[4] National Authority for Preah Vihear, Thomacheat Samdech Techo Hun Sen Village, Sraem Commune, Choam Khsant District, Cheom Ksan 13407, Preah Vihear, Cambodia; khou_eanghourt@yahoo.com

[5] Research Institute for Sustainable Humanosphere (RISH), Kyoto University, Uji, Kyoto 611-0011, Japan; akifumi_sugiyama@rish.kyoto-u.ac.jp

* Correspondence: thearith.yourk@gmail.com (Y.S.); takarice@cc.tuat.ac.jp (T.M.); yfujii@cc.tuat.ac.jp (Y.F.)

check for updates

Citation: Sothearith, Y.; Appiah, K.S.; Mardani, H.; Motobayashi, T.; Yoko, S.; Eang Hourt, K.; Sugiyama, A.; Fujii, Y. Determination of the Allelopathic Potential of Cambodia's Medicinal Plants Using the Dish Pack Method. *Sustainability* **2021**, *13*, 9062. https://doi.org/10.3390/su13169062

Academic Editors: Alessandra Durazzo and Marc A. Rossen

Received: 19 June 2021
Accepted: 8 August 2021
Published: 13 August 2021

Publisher's Note: MDPI stays neutral with regard to jurisdictional claims in published maps and institutional affiliations.

Copyright: © 2021 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (https://creativecommons.org/licenses/by/4.0/).

Abstract: Plants produce several chemically diverse bioactive substances that may influence the growth and development of other organisms when released into the environment in a phenomenon called allelopathy. Several of these allelopathic species also have reported medicinal properties. In this study, the potential allelopathic effects of more than a hundred medicinal plants from Cambodia were tested using the dish pack method. The dish pack bioassay method specifically targets volatile allelochemicals. Twenty-five species were found to have significant inhibitory effects on lettuce radicle growth. Eleven different plant families, including Iridaceae (2), Apocynaceae (2), Poaceae (2), Sapindaceae, Araceae, Combretaceae, Orchidaceae, Clusiaceae, Zingiberaceae, Rutaceae and Asparagaceae had the plant species with high inhibitory effects. *Allophyllus serrulatus* had the highest growth inhibitory effect on lettuce radicles more than 60%, followed by *Alocasia macrorrhiza*, *Iris pallida*, *Terminalia triptera*, *Wrightia tomentosa*, *Cymbidium aloifolium*, *Garcinia villersiana* and *Kaempferia parviflora*. The candidate species were subjected to further studies to identify the volatile allelochemicals in the volatile constituents.

Keywords: allelopathy; allelochemicals; volatile compounds; dish pack method

1. Introduction

Biodiversity refers to the variety and variability of life on Earth and plays a vital role in ecological functions. The integrative use of plant biodiversity is one approach to improve food security and sustainable agriculture. Species combinations, such as multi-cropping, inter-cropping, alley farming, rotations, and cover cropping, also have positive effects on crop productivity and yield stability [1]. Interaction among plant species may include the production and release of bioactive substances that directly or indirectly influence the growth and development of other organisms in a phenomenon known as allelopathy [2]. The definition was later revised to mean any process involving the secondary metabolites produced by plants, microorganisms, viruses and fungi that influence the growth and development of agricultural and biological systems (excluding animals), including positive and negative effects [3]. The secondary metabolites associated with allelopathy released into the environment through volatilization, leaching, root exudation and the decomposition of plant residues in soil are called allelochemicals. These allelochemicals are found in different parts of various plants, such as leaf, root, rhizome, stem, flower, pollen, fruit and seed [4,5]. Allelopathy may play an important role in the biological invasion process in natural ecology. Some plants are not dominant competitors in their natural habitat, yet show strong succession when introduced to new areas [6]. Generally, allelopathy is accepted as a significant ecological factor in determining the structure and composition of plant communities [7].

Despite recent advances in the development of agrochemicals for pest control in modern agriculture, crop yields experience average losses of 35% worldwide. This is mainly due to pests, pathogens and weeds [8]. Weeds are particularly destructive: approximately 30 to 50% of producing crops are destroyed if weeds are not controlled in Asia and other continents [9–11]. More than 240 weeds have been found to have allelopathic effects on surrounding plants, whether on the same species (autotoxicity) or on other crops and weed species [12]. However, scientists in many different habitats around the world have demonstrated agrochemical pest control. Numerous allelopathic effects from plant species have been reported. For example, 84 out of 245 plant species in the Sino-Japan floristic region have been shown to cause significant inhibitory activity; of these, 10 species showed the strongest effects [13]. The evaluation of the allelopathic potential of 83 Iranian medicinal plants found more than 80% root growth suppression of lettuce by *Peganum harmala*, *Berberis vulgaris*, *Artemisia aucheri* and *Ferulago angulate* [14]. The evaluation of allelopathic potential in medicinal plant species used in Ghana found that 75 out of 183 medicinal plant species caused a significant inhibition of lettuce radicle growth through leaf leachates [15]. Identified and isolated bioactive compounds (allelochemicals) from plants are therefore important sources for alternative sustainable and eco-friendly weed control strategies [16], especially given that organic products have increased in popularity over the last decade [17]. The secondary metabolites present in medicinal plants are thought to have relatively strong allelopathic activity. Moreover, analyzing medicinal plants to find new natural compounds is easier than analyzing other plants [2,18–20]. Some bioactive substances, including ferulic, coumaric, vanillic, caffeic and chlorogenic acids in medicinal plants have been found to inhibit plant growth [21,22]. By using the sandwich method, the previous study identified more than fifty medicinal plants with allelopathic potentials through leachates [23]. This study, therefore, collected different parts of some medicinal plants from northwestern Cambodia to examine allelopathic effects using the dish pack method under laboratory conditions.

2. Materials and Methods

2.1. Material

All the collected medicinal plant samples were oven-dried at 60 °C for 3 h at target areas and transferred to the Laboratory of the Department of International Environment and Agriculture, Tokyo University of Agriculture and Technology, Japan to test their allelopathic activities. Lettuce (*Lactuca sativa* L.) was used as a test plant material in bioassay due to its reliability in germination and its susceptibility to inhibitory and stimulatory chemicals [24].

2.2. Dish Pack Method

The dish pack method was adopted for the analysis of volatile allelochemicals of plant species. Most importantly, it allowed us to obtain very quick results, as shown in Figure 1 [25]. Therefore, it was applied to screen all collected medicinal plant species with possibly volatile substances that could influence (promote or inhibit) the growth of lettuce. Multi-well plastic dishes with six wells (36 mm × 18 mm each) were used in this experiment. The distances from the centre of the source well (where the plant sample was placed) to the centre of other wells were 41, 58, 82 and 92 mm. The source well was filled with 200 mg of oven-dried plant materials. Filter papers were laid in the other wells, then 0.75 mL of distilled water was added to each well that contained filter paper. The control treatment did not contain any plant sample in the source well. Seven lettuce seeds were placed on the filter paper in each well. The multi-well dishes were tightly sealed using cellophane tape to avoid desiccation and the loss of volatile compounds. To exclude light, aluminium foil was wrapped around the dishes and placed in an incubator (NTS Model MI-25S) at 25 °C for three days. With three replications, the radicle and hypocotyl lengths of lettuces were measured and recorded; they were then compared to the lettuce in the control during analysis. The degree of inhibition was estimated by the relationship between lettuce seedling growth inhibition and its distance from the source well.

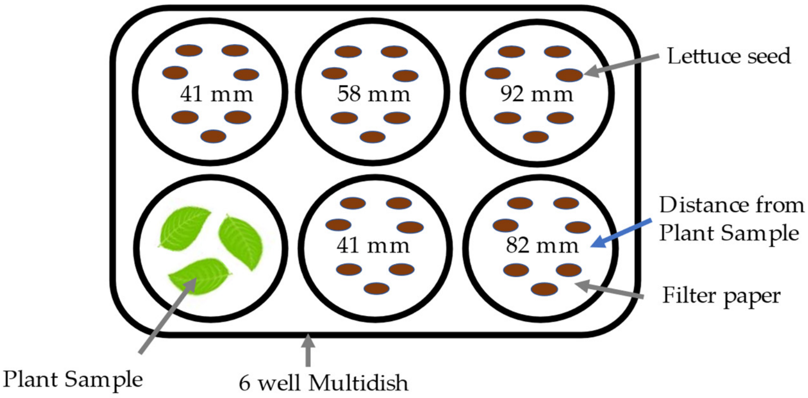

Figure 1. Dish pack method, multi-well plastic plate filled with plant sample and lettuce seeds in each well to test plant allelopathy through volatile substances.

2.3. Statistic Analysis

The treatment tested was arranged in a complete randomized design with three replicates. Statistical analysis of the experimental data was conducted with Microsoft Excel 2010. The means, standard deviations (SDs), and SD variances (SDVs) were also evaluated.

$$Inhibitory = 100 - \frac{(Average\ length\ of\ treatment\ radicle/hypocotyl)}{(Average\ length\ of\ control\ radicle/hypocotyl)} \times 100.$$

3. Results

The inhibition effects on the radicle and hypocotyl of lettuce seedlings from 195 medicinal plants using the dish pack bioassay method are shown in Table 1. The allelopathic effects of the collected medicinal plants were presented either as the promotion or inhibition of lettuce growth on the radicle and hypocotyl, which ranged from −19.2% to 68.6% and −30.2% to 67.3%, respectively. The negative value for the lettuce radicle growth indicates the stimulatory effects compared to the control. The study found several strong candidate species: 25 species from different plant families showed a significant inhibition of lettuce radicle growth among the tested plants. These species came from 11 different families, including Iridaceae (two), Apocynaceae (two), Poaceae (two), Sapindaceae, Araceae, Combretaceae, Orchidaceae, Clusiaceae, Zingiberaceae, Rutaceae and Asparagaceae. However, only *Allophyllus serrulatus* inhibited more than 60% on lettuce radicle growth among the tested plants. Radicle growth inhibition in the range of 20–30% occurred in seven species: *Alocasia macrorrhiza*, *Iris pallida*, *Terminalia triptera*, *Wrightia tomentosa*, *Garcinia villersiana*, *Cymbidium aloifolium* and *Kaempferia parviflora*. Ten further species, *Harrisonia perforate*, *Eleutherine bulbosa*, *Imperata cylindrica*, *Peliosanthes teta*, *Willughbeia edulis*, *Eleusine indica*, *Spatholobus parviflorous*, *Asplenium nidus*, *Drynaria quercifolia* and *Croton oblongifolius* demonstrated lettuce radicle inhibitory effects of between 15 and 20%. The lowest effects on lettuce radicle growth were *Kaempferia galanga*, *Afzelia xylocarpa*, *Zingiber purpureum*, *Careya sphaerica*, *Congea tomentosa*, *Pseuderanthemum latifolium* and *Ventilago cristata*.

Table 1. The radicle and hypocotyl inhibition percentages of lettuce seedlings grown using the dish pack method.

Scientific Name	Plant Families	Part Used	Inhibition Activity (%)				Criteria
			Average at 41 mm		Average for Whole Wells		
			R	H	R	H	
Allophyllus serrulatus Radlk	Sapindaceae	Leaf	68.6	67.3	63.1	63.1	***
Alocasia macrorrhiza (L.) G.Don	Araceae	Tuber	23.4	−5.22	20.5	−5.62	***
Iris pallida Lam.	Iridaceae	Rhizome	22.1	6.71	14.3	7.34	***
Terminalia triptera Stap f	Combretaceae	Stem	21.3	9.22	13.7	−1.82	**
Wrightia tomentosa Roem-Schult	Apocynaceae	Stem	21.1	9	15.9	2.12	**
Garcinia villersiana Pierre	Clusiaceae	Stem	20.4	1.32	16.2	2.11	**
Cymbidium aloifolium (Linn) Swartz.	Orchidaceae	Leaf	20.4	14.2	10.7	12.4	**
Kaempferia parviflora Wall. ex Baker	Zingiberaceae	Rhizome	20.2	8.11	8.72	4.12	**
Harrisonia perforata Merr.	Rutaceae	Bark	19.8	−4.72	−0.92	−4.53	**
Eleutherine bulbosa (Mill.) Urb.	Iridaceae	Flower	18.7	2.42	16.7	5.62	**
Imperata cylindrica Beauv	Poaceae	Leaf	18.2	15.2	12.4	9.91	**
Peliosanthes teta Andrew	Asparagaceae	Leaf	17.4	13.4	−0.54	6.32	**
Willughbeia edulis Roxb.	Apocynaceae	Stem	17.2	9.2	8.92	1.83	**
Eleusine indica (L) Gaertn	Poaceae	Leaf	17	1.34	13.9	7.32	**
Spatholobus parviflorous Kuntz.	Fabaceae	Stem	16.4	6.92	10.9	0.81	*
Asplenium nidus L.	Aspleniaceae	Leaf	15.7	4.77	9.14	7.42	*
Drynaria quercifolia (L.) J Sm	Polypodiaceae	Leaf	15.3	−5.92	9.12	−5.91	*
Croton oblongifolius Roxb.	Euphorbiaceae	Leaf	15.2	7.6	9.32	6.63	*
Kaempferia galanga Linn.	Zingiberaceae	Rhizome	14.8	17.4	8.41	11.2	*
Afzelia xylocarpa (Kurz) Craib.	Fabaceae	Bark	14.6	−8.9	7.72	−5.31	*
Zingiber purpureum Roscoe.	Zingiberaceae	Rhizome	13.9	19.5	4.62	11.6	*
Careya sphaerica Roxb.	Lecythidaceae	Bark	12.7	−3.12	13.4	3.12	*
Congea tomentosa Roxb.	Lamiaceae	Stem	12.4	21.8	0	12.1	*
Pseuderanthemum latifolium (Vahl) B. Hansen	Acanthaceae	Leaf	12.3	1.4	2.33	−3.74	*
Ventilago cristata Pierre	Rhamnaceae	Stem	12.3	0	17.6	1.82	*
Sterculia foetida Linn	Sterculiaceae	Stem	11.5	−28.4	5.07	−19.1	
Croton lachnocarpus Benth.	Euphorbiaceae	Leaf	11.4	−5.21	19.1	4.31	
Zingiber ottensii Valeton	Zingiberaceae	Rhizome	11.4	57.1	−0.92	41.6	
Ervatamia microphylla Kerr.	Apocynaceae	Leaf	11.3	8.8	5.61	1.82	
Vitex pubescens Vahl.	Lamiaceae	Stem	11.1	12.2	5.12	8.93	
Morinda tomentosa Roth	Rubiaceae	Stem	11	11.5	6.2	10.9	
Hoya diversifolia Blume	Asclepiadaceae	Leaf	10.1	2.7	9.12	4.71	
Uvaria rufa Blume	Annonaceae	Stem	9.8	15.1	−1.93	7.74	
Scoparia dulcis L	Plantaginaceae	Stem	9.42	6.94	4.12	0	
Polyalthia evecta (Pierre) Finet et Gagnep.	Annonaceae	Stem	9.23	−4.43	7.04	−2.21	
Litchi chinensis Sonn	Sapindaceae	Bark	9.04	−7.71	2.82	−5.91	
Artocarpus rigidus Blume	Moraceae	Bark	8.71	6.72	5.22	0.93	
Kalanchoe Integra Kuntze.	Crassulaceae	Stem	8.7	−0.94	9	2.24	
Hymenocardia punctata Wall. ex *Lindl.*	Euphorbiaceae	Stem	8.42	1.15	3.07	4.12	
Zizyphus cambodiana Pierre	Rhamnaceae	Stem	8.33	3.63	4.62	−2.21	
Coptosapelta flavescens Korth.	Rubiaceae	Stem	8.21	2.72	6.74	−2.91	
Ochna integerrima (Lour) Merr.	Ochnaceae	Stem	8.14	7.31	−1.43	2.72	
Curcuma aromatica Salisb.	Zingiberaceae	Leaf	8.04	2.33	2.91	−0.82	
Sindora siamensis Teysm.	Fabaceae	Bark	8.02	−0.22	0.52	3.51	
Suregada multiflora Baill.	Euphorbiaceae	Stem	8	−1.64	9.61	−1.83	
Diospyros venosa Wall.	Ebenaceae	Stem	7.26	14.1	2.12	3.91	
Gnetum montanum Markgr.	Gnetaceae	Stem	7.23	−2.6	−4.04	−3.3	
Knema globularia Warb.	Myristicaceae	Stem	7.14	−7.12	5.32	−4.5	
Stephania rotunda Linn.	Menispermaceae	Tuber	7.13	7.16	3.21	10.2	
Microcos paniculata L.	Malvaceae	Stem	7.1	6.93	3.32	6.71	
Costus speciosus (Koenig) J.E.Smith.	Costaceae	Root	7	4.74	7	4.12	
Amomum xanthioides Wall.	Zingiberaceae	Stem	6.7	8.4	6.21	0	
Oroxylum indicum (Linn.) Kurz	Bignoniaceae	Bark	6.62	11.6	4.43	4.61	
Psydrax pergracilis (Bourd.) Ridsdale	Rubiaceae	Stem	6.32	1.8	3.13	−1.82	
Bombax ceiba L.	Malvaceae	Bark	6.21	7.75	20.1	12.9	
Donax grandis Ridley	Poaceae	Stem	5.94	11.2	−0.21	6.81	
Carallia brachiata (Lour.) Merr	Rhizophoraceae	Bark	5.86	4.54	8.54	11.1	
Pouzolzia zeylanica (L) Benn.	Urticaceae	Stem	5.82	−9.42	4.61	−6.32	
Gomphrena celosioides Mart.	Amaranthaceae	Flower	5.62	−3.61	−3.71	−11	
Crinum latifolium L.	Amaryllidaceae	Bulb	5.48	8.61	0.52	2.73	
Strychnos wallichiana Steud. Ex DC.	Loganiaceae	Stem	5.44	7.32	−1.21	3.52	
Melastoma villosum L.	Melastomataceae	Stem	5.33	−8.73	7.21	−7.64	
Ixora chinensis Lam.	Rubiaceae	Leaf	5.17	−1.14	3.12	2.21	
Eupatorium odoratum (L.) R.M.King & H.Rob.	Asteraceae	Leaf	5.1	20	4.72	12.2	

Table 1. *Cont.*

Scientific Name	Plant Families	Part Used	Inhibition Activity (%)				Criteria
			Average at 41 mm		Average for Whole Wells		
			R	H	R	H	
Dipterocarpus tuberculatus Roxb	Dipterocarpaceae	Stem	4.88	−5.72	3.91	−1.82	
Licuala spinosa Wurmb	Arecaceae	Root	4.84	−30.2	0.23	−15.2	
Nepenthes kampotiana Lecomte	Nepenthaceae	Flower	4.83	−10.6	3.12	−11.1	
Smilax ovalifolia Roxb.	Smilacaceae	Stem	4.8	14.8	−0.42	3.64	
Cnestis palala (Lour.) Merr.	Connaraceae	Leaf	4.67	7.72	−4.51	−0.92	
Smilax china L.	Smilacaceae	Stem	4.65	13.1	1.62	11.2	
Dillenia pentagyna Roxb	Dilleniaceae	Stem	4.58	−12.7	1.21	−7.62	
Gonocaryum lobianum (Miers) Kurz	Icacinaceae	Stem	4.55	−13.8	2.23	−6.74	
Physalis angulata L.	Solanaceae	Root	4.52	0.82	2.71	7.42	
Irvingia malayana Olive. Ex Benn.	Irvingiaceae	Bark	4.42	−4.62	6.12	0.4	
Dioscorea hispida Dennst.	Dioscoreaceae	Tuber	4.16	8.44	0	7.82	
Lagerstroemia calyculata Kurz.	Lythraceae	Bark	4	3.81	7.24	6.34	
Syzygium polyanthum (Wight) Walp.	Myrtaceae	Bark	3.9	5.64	−4.93	−0.91	
Streblus asper Lour.	Moraceae	Stem	3.81	−6.72	4	−2.23	
Tinospora crispa (Linn) Miers ex Hook.	Menispermaceae	Stem	3.77	−3.13	−30.9	0	
Anthocephalus chinensis (Lam.)	Rubiaceae	Bark	3.46	−1.53	7.61	−0.72	
Borassus flabellifera Linn	Arecaceae	Root	3.42	−7.31	7.21	−2.81	
Cassia alata L.	Fabaceae	Stem	3.28	−9.2	−6.32	−0.91	
Mangifera duperreana Pierre	Anacardiaceae	Bark	3.23	−2.12	11.6	10.3	
Tetracera scendens (L.) Merr.	Dilleniaceae	Leaf	2.83	4.34	3.62	5.91	
Lygodium flexuosum (L.) SW.	Lygodiaceae	Leaf	2.62	−4.52	2	−4.12	
Blumea balsamifera DC.	Asteraceae	Leaf	2.41	19.6	7.52	14.3	
Diospyros decandra Lour	Ebenaceae	Bark	2.37	−4.1	10.3	3.91	
Bauhinia bassacensis Pierre	Fabaceae	Stem	2.12	10.7	9.73	6.42	
Clerodendrum schmidtii C.B.Clarke	Lamiaceae	Stem	1.97	7.74	−4.11	−11.3	
Elaeocarpus stipularis Blume	Elaeocarpaceae	Stem	1.92	−16.7	4.62	−11.4	
Memecylon laevigalum Blume	Melastomataceae	Stem	1.72	3.42	0.41	6.43	
Illigera rhodantha Hance.	Hernandiaceae	Stem	1.58	−7.62	−2	−6.73	
Phyllanthus amarus Schum.ct Thonn.	Phyllanthaceae	Stem	1.53	1.12	12.2	4.91	
Ficus hispida L.	Moraceae	Stem	1.26	8.81	−0.21	9	
Ancistrocladus tectorius (Lour.) Merr.	Ancistrocladaceae	Stem	1.18	15.1	−0.54	10.2	
Moringa oleifera Lamk	Moringaceae	Bark	1.16	−2.92	−1.21	−0.83	
Melodorum fruticosum Lour	Annonaceae	Stem	1.15	−1.65	−0.32	2.7	
Peltophorum dasyrhachis (Miq.) Kurz	Fabaceae	Bark	1.12	11.7	−9.12	7.31	
Prismatomeris tetrandra (Roxb.) K.Schum	Rubiaceae	Stem	1.1	−4.91	7.9	−8.12	
Dipterocarpus obtusifolius Teijsm.-ex-Miq	Dipterocarpaceae	Stem	0.82	4.52	−3.21	−0.93	
Macaranga triloba (Blume) Muell.Arg.	Euphorbiaceae	Stem	0.76	0.23	4.12	−1.81	
Typhonium trilobatum Schott	Araceae	Stem	0.65	−2.83	−4.31	−6.42	
Scindapsus officinalis (Roxb.) Schott	Araceae	Stem	0.54	4.81	−2.12	1.31	
Erythroxylum cambodianum Pierre	Erythroxylaceae	Stem	0.54	−2.54	−1.63	0.52	
Spirolobium cambodianum Baill.	Apocynaceae	Stem	0.52	−1.22	1	−5.24	
Caesalpinia sappan Linn.	Fabaceae	Bark	0.37	16.3	−0.52	9.73	
Melastoma mormale (Kuntze) Merr.	Melastomataceae	Stem	0.33	2.32	1	11.9	
Heliotropium indicum L.	Boraginaceae	Leaf	0.22	−9.44	−2.81	−8.82	
Eurycoma longifolia Jack	Simaroubaceae	Bark	0.17	4.51	−2.72	3.31	
Shorea roxburgii G Don	Dipterocarpaceae	Bark	0.15	3.21	−0.71	1.82	
Plumbago zeylanica L.	Plumbaginaceae	Stem	0	2.84	−2.24	3.22	
Rauwenhoffia siamensis Scheff	Annonaceae	Stem	−0.1	−9.42	−7.2	−8.21	
Scheffera elliptaca (Blume) Harms.	Araliaceae	Stem	−0.22	5.35	1.61	4.52	
Manilkara hexandra (Roxb.) Dubard	Sapotaceae	Leaf	−0.25	0.2	−1.72	2.1	
Senna siamea Lam	Fabaceae	Leaf	−0.27	−18.1	−2.71	−14.2	
Fagraea fragrans Roxb.	Loganiaceae	Stem	−0.63	14.4	3.31	10.5	
Dracaena loureiri (Gagnep.)	Asparagaceae	Bark	−0.65	12.5	1.21	11.1	
Couroupita guianensis Aubert	Lecythidaceae	Flower	−1.42	−7.12	−3.9	1.4	
Cleistanthus tomentosus Hance	Euphorbiaceae	Stem	−1.45	−8.05	0.92	−4.12	
Albizia lebbek (L.) Benth.	Mimosaceae	Stem	−1.57	13.4	−5.81	13.6	
Fhyllanthus emblica L.	Euphorbiaceae	Stem	−1.63	−9.12	−0.52	−8.53	
Alpinia conchigera Grulf	Zingiberaceae	Leaf	−1.72	−0.2	4.14	0.91	
Ficus sagitta Vahl.	Moraceae	Leaf	−1.94	−15.5	−0.52	−6.31	
Derris scandens (Roxb.) Benth.	Fabaceae	Stem	−2	−4.13	8.62	−0.91	
Andrographis paniculata (Burm.f.)	Acanthaceae	Leaf	−2.14	1.1	9.9	−1.31	
Pandanus capusii Marc	Pandanaceae	Root	−2.33	−13.4	−8	−15.3	
Streptocaulon juventas Merr.	Apocynaceae	Stem	−2.37	3.31	0.22	3.83	
Dioscorea bulbifera L.	Discoreaceae	Tuber	−2.52	0.44	−1.41	−2.52	

Table 1. *Cont.*

Scientific Name	Plant Families	Part Used	Inhibition Activity (%)				Criteria
			Average at 41 mm		Average for Whole Wells		
			R	H	R	H	
Gnetum latifolium Blume	Gnetaceae	Stem	−2.55	4.73	−7.41	−0.44	
Entada phaseoloides Merr.	Fabaceae	Fruit	−2.6	3.24	−4.51	−7.23	
Mallotus paniculatus (Lam.) Mull.Arg.	Euphorbiaceae	Stem	−2.64	−4.6	−7.92	−2.92	
Schleicheria oleosa (Lour.) Oken.	Sapindaceae	Stem	−2.8	0.5	−11.2	−1.91	
Elephantopus scaber L.	Asteraceae	Leaf	−3	−13.3	−4.12	−11.6	
Solanum torvum Swartz	Solanaceae	Stem	−3.11	0	5.31	2.11	
Glycosmis pentaphylla (Retz) Correa	Rutaceae	Stem	−3.24	−7.32	−2.53	−3.81	
Acalypha boehmerioides Miq.	Euphorbiaceae	Leaf	−3.41	−10.2	−6.12	−11.4	
Lagerstroemia floribunda Jack.	Lythraceae	Bark	−3.57	−5.4	−4.31	−4.9	
Micromelum falcatum (Lour.) Tanak	Rutaceae	Stem	−3.58	−10.4	−6.33	−10.4	
Ficus benjamina L.	Moraceae	Stem	−4.1	−3	3.7	6.12	
Hydnophytum formicarium Jack	Rubiaceae	Tuber	−4.12	9.53	−6.04	6.6	
Capparis micracantha DC.	Capparaceae	Stem	−4.21	8.34	0.23	6.92	
Terminalia corticosa Pierre.	Combretaceae	Bark	−4.24	2.83	−11.8	−3.72	
Pteridium aquilinum (L) Kuhm.	Dennstaedtiaceae	Leaf	−4.45	2.62	−5.61	5.32	
Sida rhombifolia L.	Malvaceae	Root	−4.48	−12.9	−5.4	−7.81	
Cananga latifolia Finet et Gagnep	Annonaceae	Stem	−4.51	1.2	−1	3.31	
Parinari anamensis Hance	Chrysobalanaceae	Bark	−4.56	−1.64	0.2	−0.92	
Gardenia philastrei Pierre-ex-Pit.	Rubiaceae	Stem	−4.72	−4.21	−6.91	−13.4	
Parameria laevigata (Juss.) Moldenke	Apocynaceae	Bark	−4.74	−0.72	−7.52	−3.21	
Alstonia scholaris R-Br	Apocynaceae	Bark	−5.1	3.37	−5.91	0.9	
Tiliacora triandra Diels	Menispermaceae	Stem	−5.15	−3.83	−3.81	−3.34	
Dracaena angustifolia Roxb.	Asparagaceae	Leaf	−5.3	2.65	−6.74	−1.06	
Holarrhena curtisii King &Gamble	Apocynaceae	Leaf	−5.35	−1.44	−7.23	0	
Parabarium micranthum (A.DC.) Pierre	Apocynaceae	Leaf	−5.41	−4.82	−1.72	−6.51	
Dialium cochinchinense Pierre	Fabaceae	Bark	−5.71	13.3	−7.72	5.43	
Jasminum nobile C.B.Clarke	Oleaceae	Stem	−5.78	−14.3	−2.91	−2.7	
Melaleuca cajuputi Powell	Myrtaceae	Leaf	−5.79	−4.84	1.31	0.32	
Hymenodictyon excelsum (Roxb) w.	Rubiaceae	Leaf	−5.8	−7.11	3.11	−2.81	
Derris elliptica (Wall.) Benth.	Fabaceae	Stem	−6.21	7.72	−1.62	5.9	
Leea rubra Bl.	Vitaceae	Stem	−6.23	−8.32	−2.11	−13.8	
Rhodomyrtus tomentosa (Ait) Hassk	Myrtaceae	Leaf	−6.28	14.2	−6.08	6.31	
Brucea javanica (Linn) Merr.	Simaroubaceae	Stem	−6.31	−8.33	−4.81	−10.1	
Mimosa pudica Linn.	Fabaceae	Leaf	−6.6	−5.64	0.72	−0.7	
Lygodium conforme C. Chr.	Lygodiaceae	Leaf	−7.4	5.42	1.41	8.6	
Adina cordifolia Hok. F	Rubiaceae	Stem	−7.5	2.81	−10.7	0	
Aquilaria crassna Pierr.	Thymeleaceae	Root	−7.52	−5.62	−0.92	−2.71	
Ficus pumila L.	Moraceae	Leaf	−7.55	12.2	−5.72	7.71	
Scleria terrestris (L.) Fassett	Cyperaceae	Leaf	−7.72	−25.6	−2.61	−15.7	
Calamus rudentum Lour.	Arecaceae	Stem	−7.82	−12.1	−0.8	−4.04	
Neonauclea sessilifolia (Roxb.)Merr.	Rubiaceae	Bark	−7.9	8.93	−4.3	−2.51	
Broussonetia papyrifera (L.) L'Hér. ex Vent.	Urticaceae	Stem	−7.9	−1.9	−10.1	−3.2	
Diospyros nitida Merr.	Ebenaceae	Stem	−8	0.92	−3	3.81	+
Zizyphus oeniplia Mill	Rhamnaceae	Stem	−8.12	−8.42	−9.08	−5.62	+
Cyclea barbata Miers	Menispermaceae	Leaf	−8.41	−5.95	−9.11	−3.63	+
Dillenia ovata Wall. ex Hook.f.	Dilleniaceae	Bark	−8.44	−6.14	−9.8	−9.43	+
Homonoia riparia Lour.	Euphorbiaceae	Bark	−8.49	8.34	−6.32	2.31	+
Colona auriculata (Desv.) Craib	Tiliaceae	Stem	−9.71	−6.08	−11.5	−8.6	+
Mussaenda cambodiana Pirrl ex Pit	Rubiaceae	Stem	−9.77	−0.62	−10.6	−6.83	+
Pandanus tectorius Parkinson ex Du Roi	Pandanaceae	Leaf	−10	−8.34	−7.05	−10.1	+
Cyperus rotundus Linn.	Cyperaceae	Leaf	−10.3	−19.2	−6.91	−15.7	+
Aganosma marginata G. Don	Apocynaceae	Stem	−10.7	−0.92	−15.2	2.61	+
Mesua ferrea L	Calophyllaceae	Leaf	−10.7	12.5	−10.2	5.92	+
Lindernia crustacea (L.) F.Muell.	Linderniaceae	Stem	−10.9	5.63	−1.44	7.82	+
Zanthoxylum rhetsa DC.	Rutaceae	Bark	−11.4	9.56	−11.4	−7.11	+
Walsura villosa Wall. Ex Hiern.	Meliaceae	Bark	−12.4	−5.24	−9.71	−1.32	+
Acacia harmandiana (Pierre) Gagnep.	Fabaceae	Bark	−12.5	−13.1	−15.7	−4.1	++
Ampelocissus matinii Planch	Vitaceae	Stem	−13.1	0.52	−9.91	−0.92	++
Euphorbia hirta Linn.	Euphorbiaceae	Leaf	−13.3	−20.8	−13.5	−15.7	++
Madhuca butyrospermoides A.Chev.	Sapotaceae	Bark	−13.3	−2.1	−7.94	−1.44	++

Table 1. *Cont.*

Scientific Name	Plant Families	Part Used	Inhibition Activity (%)				Criteria
			Average at 41 mm		Average for Whole Wells		
			R	H	R	H	
Millingtonia hortensis Linn	Bignoniaceae	Stem	−13.4	−5.42	−9.71	2.23	++
Phyllanthus reticulatus Poir	Euphorbiaceae	Stem	−14.1	−14.1	−10.5	−12.9	++
Randia tomentosa Bl.	Rubiaceae	Stem	−15.4	−3.61	−12.4	1.41	++
Anacardium occidentale Linn	Anacardiaceae	Bark	−15.9	−14.3	−10.1	−6.74	++
Salacia chinensis Linn.	Celastraceae	Stem	−15.9	2.54	−12.8	6.72	++
Ficus hirta Vahl var roxburghii (Miq).	Moraceae	Stem	−16	−1.72	−12.8	−1.33	++
Sterculia lychnophora Hance	Sterculiaceae	Stem	−19.2	−10.2	−12.1	−0.42	+++

Note: Criteria (*), (**) and (***) refer to radicle elongation shorter than the mean value plus 1.0(SD), 1.5(SD) and 2(SD)—that is, SDV = 12, 17 and 22, respectively. + Criteria (+), (++) and (+++) refer to radicle elongation longer than the mean value minus 1.0(SD), 1.5(SD) and 2(SD)—that is, SDV = −8, −13 and −18, respectively.

4. Discussion

In the Sapindaceae plant family, *Allophylus serratus*, a large shrub found all over India, showed a stronger inhibition activity through volatile compounds than *Litchi chinensis* and *Schleicheria oleosa. Allophylus serratus* is used as an anti-inflammatory and carminative due to its strong pharmacological activity. This plant is also used to treat numerous medical conditions, such as elephantiasis, oedema and bone fractures, as well as several gastrointestinal disorders, including dyspepsia, anorexia and diarrhea [26]. Bioactive substances contained in *Allophylus serratus* include phenolic compounds, flavonoids, tanning substances, steroids, alkaloids and saponins were reported [27]. Other compounds isolated from *Allophylus serratus*, such as quercetin, pinitol, luteolin-7-O-β-D-glucopy-ranoside, rutin and apigenin-4-O-β-D-glucoside. However, only rutin showed an increase in osteoblast mineralization, as assessed by alizarin extraction; its use has been suggested for menopausal osteoporosis [28].

Another interesting species is *Alocasia macrorrhiza* (common name Elephant Ear Taro), a giant plant with distinctive leaves, which is mostly used for ornamental purposes and belongs to the Araceae family [29]. Elephant Ear Taro is a massive herb formed by a thick erect trunk in large plants and up to 4 m in height; its leaves are held erect with petioles (leaf stalks) that are up to 130 cm long [30]. It has antifungal, antidiuretic, laxative, antitubercular and antioxidant properties; it also features other compounds such as flavonoids, oxalic acid, cyanogenic glycosides, alocasin, cholesterol, amino acids, gallic acid, malic acid, ascorbic acid, succinic acid, glucose, fructose, sucrose and beta-lectins [31]. Additionally, 14 compounds have been isolated and identified from giant taro, including 5 new lignan amides, 1 new monoindole alkaloid and 8 known compounds [32].

Iris pallida from the Iridaceae family also showed potential inhibitory effects. *Iris* contains up to 80 genera and 300 species that are distributed worldwide; it is abundant and diversified in the regions of Southern Africa and Asia. Many of these species are common ornamental plants [33]. *Iris pallida,* known as the sweet iris, is a perennial herb native to the Dalmatian coast, Croatia; it is mostly cultivated for its essential oils and use in aromatherapy and traditional medicine [34,35]. The rhizomes of *Iris pallida* found to have strong allelopathic activity contain the isoflavones irigenin, iristectorigenin A, nigericin, nigricanin, irisflorentin, iriskumaonin methyl ether, irilone, iriflogenin and others [23,36–39]. In total, 16 and 26 volatile components were found from the essential oil of rhizomes and leaves, respectively. Dihydro-β-irone, α-irone, trans-2,6-γ-irone, β-isometilionone; benzophenone and other dominant terpenes, including 4-isobutylphenone, benzophenone, hexahydrofarnesyl acetone, neofitadien and squalene were also reported [40]. The bioactive substances, including irones in *iris* rhizomes could offer commercial potential in the form of iris essential oil [41].

In the Rutaceae family, *Harrisonia perforata* Merr, known as a prickly shrub, is native to China but widely distributed across Southeast Asia. This plant is nearly upright, growing up to 6 m tall. Several parts of this prickly shrub are gathered from the wild and used locally as medicines to treat some diseases, such as dysentery and cholera, and to relieve itching. It is also reported that its root when dried contains antipyretic and anti-inflammatory properties that are used to deal with wound healing and diarrhea [42]. The leaves, fruits, branches and roots of *Harrisonia perforate* have been reported to contain several chromones, limonoids, triterpenoids and prenylated polyketides, including harrisotone A–E, haperforine A, haperforine E, 12-desacetylhap-erforine A, haperforine C2, haperforine F, haperforine G, Foritin, harrisonol A, peucenin-7-methyl ether, *O*-methyla-lloptaeroxylin, perforatic acid, eugenin, saikochromone A, greveichromenol and perforamone A–D [43]; *β*-sitosterol, obacunone, herteropeucenin-7-methyl ether, perforatic acid and harrisonin [44–47]; and harperforatin, harperfolide and harperamone [48].

5. Conclusions

This study presents a preliminary analysis of the potential volatile allelopathic effects of some medicinal plants in Cambodia. The revealed data could help future researchers to isolate and identify volatile allelochemicals to demonstrate bio-herbicides for sustainable weed control. *Allophyllus serrulatus*, which showed the highest inhibitory effect, was recommended for the further identification and characterization of allelopathic substances.

Author Contributions: Conceptualization, Y.S., K.S.A., H.M. and Y.F.; methodology, K.S.A., H.M. and Y.F.; software, Microsoft Office 2016; validation, T.M., K.S.A. and K.E.H.; Resources, A.S. and Y.F.; Funding acquisition, A.S. and Y.F.; data curation, Y.S. and K.E.H.; writing—initial draft preparation, Y.S.; writing—review and editing, Y.S., K.S.A., S.Y. and Y.F.; supervision, T.M. and Y.F. All authors have read and agreed to the published version of the manuscript.

Funding: This research received funding from the Ministry of Education, Culture, Sports, Science, and Technology (MEXT), Japan. This work was also partly supported by JST CREST Grant Number JPMJCR17O2 and JSPS KAKENHI Grant Number 26304024.

Data Availability Statement: No new data were created or analyzed in this study.

Acknowledgments: The authors thank the Japanese Ministry of Education, Culture, Sports, Science, and Technology (MEXT), JST CREST and JICE/JDS for providing the scholarship to the first author at the Tokyo University of Agriculture and Technology. We also gratefully acknowledge to the Ministry of Environment, the Ministry of Agriculture, Forestry and Fisheries, the Provincial Department of Environment, Siem Reap Province and the Local Community at Phnom Kulen National Park, Cambodia for supporting and assisting in sample collection and transfer for this research study.

Conflicts of Interest: The authors declare no conflict of interest.

References

1. FAO. Biodiversity for Food and Agriculture Contributing to Food Security and Sustainability in a Changing World. In Proceedings of the Workshop Report, Rome, Italy, 14–16 April 2010.
2. Rice, E.L. *Allelopathy*, 2nd ed.; Academic Press: New York, NY, USA, 1984.
3. Torres, A.; Oliva, R.M.; Castellano, D.; Cross, P. First World Congress on Allelopathy. In *A Science of the Future, SAI*; University of Cádiz: Andalusia, Spain, 1996; p. 278.
4. Fujii, Y.; Hiradate, S. *Allelopathy: New Concepts and Methodology*; Science Publishers Inc.: Enfield, NH, USA, 2007.
5. Turk, M.A.; Tawaha, A.M. Allelopathic effect of black mustard (*Brassica nigra* L.) on germination and growth of wild oat (*Avena fatua* L.). *Crop Prot.* **2003**, *22*, 673–677. [CrossRef]
6. Driesche, R.G.V.; Bellows, T.S. Pest Origins, Pesticides and the History of Biological Control. In *Biological Control*; Chapman and Hall: New York, NY, USA, 1996; pp. 1–20.
7. Scrivanti, L.R.; Zunino, M.P.; Zygadlo, J.A. *Tagetes minuta* and *Schinus areira* essential oils as allelopathic agents. *Biochem. Syst. Ecol.* **2003**, *31*, 563–572. [CrossRef]
8. Oerke, E.C. Centenary Review Crop losses to pests. *Agric. Sci.* **2006**, *144*, 31–43. [CrossRef]
9. Swarbrick, B.L.; Mercado, J.T. Weed Science and Weed Control in Southeast Asia. In *FAO Plant Production and Protection*; Food and Agriculture Organization of the United Nations: Rome, Italy, 1987; p. 81.
10. Oerke, E.C.; Dehne, H.W. Global crop production and the efficacy of crop protection—Current situation and future trends. *Eur. J. Plant Pathol.* **1997**, *103*, 203–215. [CrossRef]
11. Karim, S.M.R.; Iqbal, T.M.T.; Islam, N. Relative yields of crops and crop losses due to weed competition in Bangladesh. *Pak. J. Sci. Ind. Res.* **1999**, *41*, 318–324.

12. Colquhoun, J.B. Allelopathy in Weeds and Crops: Myths and Facts. In Proceedings of the Wisconsin Fertilizer, Aglime and Pest Management Conference, Madison, WI, USA, 17–19 January 2006; Volume 45, pp. 318–319.
13. Appiah, K.S.; Zhenhao, L.; Ren, S.Z.; Shiming, L.; Oikawa, Y.; Fujii, Y. Determination of allelopathic potentials in plant species in Sino—Japanese floristic region by sandwich method and dish pack method. *Int. J. Basic Appl. Sci.* **2015**, *4*, 381–394. [CrossRef]
14. Mardani, H.; Azizi, M.; Osivand, A.; Fujii, Y. Evaluation of Allelopathic Activity of Iranian Medicinal Plants by Sandwich Method. *J. Weed Sci. Technol.* **2014**, *53*, 85.
15. Appiah, K.S. Evaluation of Allelopathic Potentials in Medicinal Plant Species Used in Ghana. Master's Thesis, Tokyo University of Agriculture and Technology, Tokyo, Japan, 2016.
16. Khanh, T.D.; Hong, N.H.; Xuan, T.D.; Chung, I.M. Paddy weed control by medicinal and leguminous plants from Southeast Asia. *Crop Prot.* **2005**, *24*, 421–431. [CrossRef]
17. Willer, H.; Kilcher, L. Training Manual for Organic Agriculture: The World of Organic Agriculture. In *Statistics and Emerging Trends 2009*; IFOM: Bonn, Germany, 2009.
18. Chevallier, A. *The Encyclopedia of Medicinal Plants: A Practical Reference Guide to over 550 Key Herbs & Their Medicinal Uses*; Dorling Kindersley: London, UK, 1996.
19. Michael, W. Introduction: Biochemistry, Role and Biotechnology of Secondary Metabolites. *Annu. Plant Rev.* **1999**, *2*, 1–16.
20. Fujii, Y.; Parvez, S.S.; Parvez, M.M.; Ohmae, Y.; Iida, O. Screening of 239 Medicinal Plant Species for Allelopathic Activity using the Sandwich Method. *Weed Biol. Manag.* **2003**, *3*, 233–241. [CrossRef]
21. Modallal, N.M.; Al-Charchafchi, F.M.R. Allelopathic effect of *Artemisia harba* alba on germination and seedling growth of Anabasis setifera. *Pak. J. Biol. Sci.* **2006**, *9*, 1795–1798. [CrossRef]
22. Nazir, T.; Uniyal, A.K.; Todaria, N.P. Allelopathic behavior of three medicinal plant species on traditional agriculture crops of Garhwal Himalaya. *India Agrofor. Syst.* **2007**, *69*, 183–187. [CrossRef]
23. Sothearith, Y.; Appiah, K.S.; Motobayashi, T.; Watanabe, I.; Somaly, C.; Sugiyama, A.; Fujii, Y. Evaluation of Allelopathic Potentials from Medicinal Plant Species in Phnom Kulen National Park, Cambodia by the Sandwich Method. *Sustainability* **2021**, *13*, 264. [CrossRef]
24. Fujii, Y.; Shibuya, T.; Yasuda, T. Survey of Japanese weed and crops for the detection of water-extractable allelopathic chemicals using Richards' function fitted to lettuce germination test. *Weed Res. Jpn.* **1990**, *35*, 362–370.
25. Fujii, Y.; Matsuyama, M.; Hiradate, S.; Shimozawa, H. Dish pack method: A new bioassay for volatile allelopathy. *Thymus* **2005**, *2*, 493–497.
26. Dharmani, P.; Mishra, P.K.; Maurya, R.; Chauhan, V.S.; Palit, G. Allophylus serratus: A plant with potential anti-ulcerogenic activity. *J. Ethnopharmacol.* **2005**, *99*, 361–366. [CrossRef]
27. Jemal, K.; Sandeep, B.V.; Pola, S.R. Review Article a Review on Medicinal Importance of *Allophylus serrattus* and *Premna tomentosa*. *Int. J. Curr. Res.* **2015**, *7*, 21034–21039.
28. Kumar, M.; Rawat, P.; Dixit, P.; Mishra, D.; Gautam, A.K. Anti-osteoporotic constituents from Indian medicinal plants. *Phytomedicine* **2010**, *17*, 993–999. [CrossRef]
29. Ongpoy, R.C., Jr. The Medicinal Properties of the Alocasia Genus: A Systematic Review. *JAASP Res. Pap.* **2017**, *6*, 1.
30. Available online: http://www.kew.org/science-conservation/plants-fungi/alocasia-macrorrhizos-elephant-ear-taro (accessed on 10 August 2021).
31. Singh, S.K.; Patel, J.R.; Dangi, A.; Bachle, D.; Katariya, R.K. Review Paper on *Alocasia macrorrhiza* Indian Medicinal Plant. *Eur. J. Pharm. Med. Res.* **2017**, *4*, 366–375.
32. Huang, W.; Li, C.; Wang, Y.; Yi, X.; He, X. Anti-inflammatory lignanamides and monoindoles from *Alocasia macrorrhiza*. *Fitoterapia* **2017**, *117*, 126–132. [CrossRef]
33. Goldblatt, P.; Manning, J.C.; Demissew, S.S. Two new species of *Zygotritonia* Mildbr. (Iridaceae: Crocoideae) from eastern tropical Africa with notes on the morphology of the genus. *S. Afr. J. Bot.* **2015**, *96*, 37–41. [CrossRef]
34. DeBaggio, T.; Tucker, A.O. *The Encyclopedia of Herbs: A Comprehensive Reference to Herbs of Flavor and Fragrance*, 2nd ed.; Timber Press Inc.: Portland, OR, USA, 2009; pp. 266–267.
35. Troy, D.B. (Ed.) *Remington: The Science and Practice of Pharmacy*, 21st ed.; Lippincott William and Wilkins: Philadelphia, PA, USA, 2006; p. 1069.
36. Wang, H.; Cui, Y.; Zhao, C. Flavonoids of the genus Iris (Iridaceae). *Mini Rev. Med. Chem.* **2010**, *10*, 643–661. [CrossRef]
37. Iwashina, T.; Ootani, S. Flavonoids of the genus Iris: Structures, distribution and function. *Ann. Tsukuba Bot. Gard.* **1998**, *17*, 147–183.
38. Kukula-Koch, W.; Sieniawska, E.; Widelski, J.; Urjin, O.; Glowniak, P.; Skalicka-Woźniak, K. Major secondary metabolites of *Iris* spp. *Phytochem. Rev.* **2015**, *14*, 51–80. [CrossRef]
39. Roger, B.; Jeannot, V.; Fernandez, X.; Cerantola, S.; Chahboun, J. Characterisation and Quanti fi cation of Flavonoids in *Iris germanica* L. and *Iris pallida* Lam. Resinoids from Morocco. *Phytochem. Anal.* **2011**, *23*, 450–455. [CrossRef]
40. Mykhailenko, O. Composition of Volatile Oil of *Iris pallida* Lam. *From Ukraine. Turk. J. Pharm. Sci.* **2018**, *15*, 85–90. [CrossRef]
41. Board, N. Modern technology of perfumes, flavours and essential oils. *Natl. Inst. Ind. Res.* **2005**, *2*, 282–283.
42. Fern, K.; Tropical Plants Database. Tropical.Theferns.Info. 2019. Available online: tropical.theferns.info/viewtropical.php?id=Harrisonia+perforata (accessed on 21 July 2021).

43. Tuntiwachwuttikul, P.; Phansa, P.; Pootaeng-On, Y.; Taylor, W.C. Chromones from the branches of *Harrisonia perforata*. *Chem. Pharm. Bull.* **2006**, *54*, 44–47. [CrossRef] [PubMed]
44. Khuong-Huu, Q.; Chiaroni, A.; Riche, C.; Nguyen-Ngoc, H.; Nguyen-Viet, K.; Khuong-Huu, F. New rearranged limonoids from *Harrisonia perforata*. *J. Nat. Prod.* **2000**, *63*, 1015–1018. [CrossRef]
45. Khuong-Huu, Q.; Chiaroni, A.; Riche, C.; Nguyen-Ngoc, H.; Nguyen-Viet, K.; Khuong-Huu, F. New rearranged limonoids from *Harrisonia perforata*. III. *J. Nat. Prod.* **2001**, *64*, 634–637. [CrossRef] [PubMed]
46. Thu, H.D.T.; Tri, M.V.; Ngoc, N.B.; Sévenet, T.; Païs, M.; Martin, M.T. Foritin, a new limonoid from *Harrisonia perforata*. *Nat. Prod. Lett.* **2000**, *14*, 191–195. [CrossRef]
47. Yin, S.; Chen, X.; Su, Z.S.; Yang, S.P.; Fan, C.Q.; Ding, J.; Yue, J.M. Harrisotones A–E, five novel prenylated polyketides with a rare spirocyclic skeleton from *Harrisonia perforata*. *Tetrahedron* **2009**, *65*, 1147–1152. [CrossRef]
48. Choodej, S.; Sommit, D.; Pudhom, K. Rearranged limonoids and chromones from *Harrisonia perforate* and their anti-inflammatory activity. *Bioorg. Med. Chem. Lett.* **2013**, *23*, 3896–3900. [CrossRef] [PubMed]