Original Article

Pharmacological, ethnopharmacological, and botanical evaluation of subtropical medicinal plants of Lower Kheng region in Bhutan

Phurpa Wangchuk\textsuperscript{a,}\textsuperscript{*}, Karma Yeshi\textsuperscript{b}, Kinga Jamphel\textsuperscript{c}

\textsuperscript{a} Centre for Biodiscovery and Molecular Development of Therapeutics, Australian Institute of Tropical Health and Medicine, James Cook University, Cairns, Queensland, Australia
\textsuperscript{b} Wangbama Central School, Ministry of Education, Thimphu, Bhutan
\textsuperscript{c} Non-communicable Disease Division, Department of Public Health, Ministry of Health, Thimphu, Bhutan

A R T I C L E   I N F O

Article history:
Received 13 May 2017
Received in revised form 4 August 2017
Accepted 17 August 2017
Available online 1 September 2017

Keywords:
Bhutanese Sowa Rigpa medicine
ethnobotany
Lower Kheng
medicinal plants
pharmacological activities

A B S T R A C T

Background: The Bhutanese Sowa Rigpa medicine (BSM) uses medicinal plants as the bulk ingredients. Our study was to botanically identify subtropical medicinal plants from the Lower Kheng region in Bhutan, transcribe ethnopharmacological uses, and highlight reported pharmacological activities of each plant.
Methods: We freely listed the medicinal plants used in the BSM literature, current formulations, and the medicinal plants inventory documents. This was followed by a survey and the identification of medicinal plants in the Lower Kheng region. The botanical identification of each medicinal plant was confirmed using The Plant List, eFloras, and TROPICOS. Data mining for reported pharmacological activities was performed using Google Scholar, Scopus, PubMed, and SciFinder Scholar.
Results: We identified 61 subtropical plants as the medicinal plants used in BSM. Of these, 17 plants were cultivated as edible plant species, 30 species grow abundantly, 24 species grow in moderate numbers, and only seven species were scarce to find. All these species grow within the altitude range of 100–1800 m above sea level. A total of 19 species were trees, and 13 of them were shrubs. Seeds ranked first in the parts usage category. Goshing Gewog (Block) hosted maximum number of medicinal plants. About 52 species have been pharmacologically studied and only nine species remain unstudied.
Conclusion: Lower Kheng region is rich in subtropical medicinal plants and 30 species present immediate economic potential that could benefit BSM, Lower Kheng communities and other Sowa Rigpa practicing organizations.

© 2017 Korea Institute of Oriental Medicine. Published by Elsevier. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).

\textsuperscript{*} Corresponding author at: Centre for Biodiscovery and Molecular Development of Therapeutics, Australian Institute of Tropical Health and Medicine, James Cook University, Cairns campus, McGregor Rd., Smithfield, Queensland 4878, Australia.
E-mail address: phurpaw@yahoo.com (P. Wangchuk).

http://dx.doi.org/10.1016/j.imr.2017.08.002
2213-4220/© 2017 Korea Institute of Oriental Medicine. Published by Elsevier. This is an open access article under the CC BY-NC-ND license (http://creativecommons.org/licenses/by-nc-nd/4.0/).
1. Introduction

Plants are the basis of both traditional medicines (TMs) and modern drug discoveries. More than 50,000 plant species are used in TM worldwide and majority of them are being used in Asian medicines.\(^2\) Asian medicines comprise oral-based folkloric medicines (local healing system) and the scholarly TM systems. While most of the folkloric medicines remain neglected, undocumented, and are becoming rare or extinct due to fast-paced modernization, the scholarly TM systems still thrive in many Asian countries including Bhutan.

In Bhutan, while some traditional physicians argue that Sowa Rigpa originated in the 8th century CE with the advent of Mahayana Buddhism, many scholars believe that it was only in 1616 that Lama Zhabdrung Nawang Namgyal laid written foundation to this medical system. The Bhutanese Sowa Rigpa medicine (BSM) belong to the larger corpus of the Tibetan scholarly medical (TSM) system, which was derived from Chinese Traditional Medicine, Indian Ayurvedic Medicine, Greco-Roman medicine, and the Persian medicine (Galenos).\(^3\) However, the country’s culture, tradition, local medical practices, geography, and vegetation influenced the way BSM evolved independently over many centuries, making it specific to Bhutan. The similarities and differences between TSM and BSM was described by us previously.\(^6\) One significant difference between TSM and BSM is the use of medicinal plants.

BSM was integrated with modern medical systems in 1967 and this integration policy facilitated the establishment of a TM university, pharmaceutical factory, and 58 TM hospitals and units in the country. While the medical university develops human resources required for providing TM services, the pharmaceutical factory [known as the Menjong Sorig Pharmaceutical (MSP)] produces more than 100 different polyingredient herbal formulations. These formulations are prepared into different dosage forms and are distributed free-of-cost to the traditional hospitals and units wide across the country. The BSM formulations uses both high- (HAMP) and low-altitude medicinal plants (LAMP). HAMP are currently collected from the alpine mountains of Lingzhi region (2500–6000 meters above sea level (masl)). LAMP are collected from the temperate and subtropical valleys of Langthel region (600–2000 masl). Lingzhi and Langthel regions have been the collection sites for MSP for more than 48 years and the pressure on the medicinal plants population in those two areas have increased significantly over the recent years. The government’s policy to expand the TM health care services to all corners of the country would add even more pressure to the plant population in the current collection centers. The collection of medicinal plants on a rotational basis from different collection sites in the country is expected to reduce their ecological pressure. Recently, an alternative collection site for HAMP has been identified in Choekhor Gewog under Bumthang District (Central Bhutan) and Dagala Gewog in Thimphu (Western Bhutan).

However, no study has yet been conducted to determine the suitability of an alternative collection site for LAMP. Therefore, urgent need to identify more places with LAMP has been discussed at various levels of the Ministry of Health meetings within Bhutan. In line with this necessity, we conducted a field survey and the botanical identification of LAMP in the Lower Kheng region, which is in the central-southern belt of the subtropical zone in Bhutan (Fig. 1). Our survey/study of medicinal plants from Lower Kheng region addresses the important research questions including: Does Lower Kheng region host as many medicinal plants as Langthel Gewog under Trongsa district? What type of medicinal plants grow there? What is their status? Could Lower Kheng be used as an alternative collection site for harvesting LAMP in bulk quantities for MSP? Could Lower Kheng people benefit through the medicinal plants collection program? Are there any scientific studies conducted to verify the ethnopharmacological uses of these plants? Our ethnobotanical survey findings involving Lower Kheng region are presented here for the first time.

2. Methods

2.1. Study area and plant sample size

The study areas included the following Gewogs (blocks of villages; Fig. 1): (1) Phangkhar Gewog (Pantang, Shilingtoed, Kulumtay villages); (2) Goshing Gewog (Lichibi, Buddhhashi, Lamtang villages); and (3) Ngangla Gewog (Ribarty, Manas, Sonamthang, Kagtong villages). Few sub-villages, which are made of 4–15 households, were combined with the bigger villages. For example, Lichibi village features 10 villages including Thimbi, Samcholing, Mathangor, Lempong, Umling, Tongphu, Dungur, Shantang, Drangling, and Toenkharr. Similarly, Sonamthang village is made of four villages including Sonamthang, Tungudomba, Marangdud, and Panbang town area. Buddha includes five villages: proper Buddha, Bobtsar, Solongmed, Surphang, and Selingbee. All three of these Gewogs are today accessible by motor roads.

The criteria and reasons for choosing these areas as our ethnobotanical study areas were: (1) there was unsubstantiated/anecdotal claim about the lush growth of LAMP in the region; (b) no ethnobotanical study has been conducted in this region to date; and (3) Lower Kheng people are poor and their engagement in the medicinal plants collection, cultivation, and marketing programs could help them generate cash income. We used purposive and convenience sampling method to identify and locate the medicinal plants in these three Gewogs. The plant population or the sample size was irrelevant in this study since our survey included all the medicinal plants known and available within the study areas.

2.2. Study design, survey methods, and team reflexivity

Our study was a literature-guided ethnopharmacological, pharmacological and ethnobotanical identification study. We first reviewed the current traditional medicine formulations and the Sowa Rigpa medicinal plants list maintained by MSP.\(^5\) For HAMP identification, we followed similar protocols as described by us previously including the translation of traditional medical uses of the plants.\(^6\) The research team, comprising a Drungtsho (traditional physician from National Traditional Medicine Hospital), a Senior Smenpa (traditional clinical assistant from MSP), a Chief Pharmacist (Head of
MSP), and two research assistants, then visited the study areas (Fig. 1) for field observation, photographing, herbarium specimen collection, and spot identification of the medicinal plants based on the BSM plant characterization protocols in September 2009. We used convenience sampling methods. The vegetation, habitat, local plant name, locality name, species abundance, and the altitude of the place, where the medicinal plants were spotted at the time of the survey, were recorded at each field site. Altitudes were recorded using a hand-held Garmin Etrex GPS-Altimeter unit (Garmin Ltd., USA) and the pictures of live plants were also taken at the time of our field visit. Herbarium specimens were pressed, prepared, and deposited at MSP in Bhutan. Selected elderly farmers from the study areas were interviewed for their knowledge on the edible and socioculturally useful plants growing in their region. Ethnobotanical identification of the medicinal plants was confirmed either at the base-camp or upon returning to MSP based on the series of original publications on flora of Bhutan.\cite{9,17} and other Himalayan plant publications.\cite{18,19} The botanical names were also confirmed through The Plant List,\cite{20} eFloras,\cite{21} and TROPICOS.\cite{22} Data mining for the reported biological or pharmacological activities of each plant was performed using Google Scholar, Scopus, PubMed, and SciFinder Scholar.

### 2.3. Data management, criteria setting, and analysis

Each plant species was scored for their status as “abundant”, “moderate”, and “rare”. The plants that had less than 10 counts or citations in the study areas were scored as rare or available in limited number. Those plants with 10–50 counts/citation in the area at the time of the survey were scored as moderately available and those with more than 50 counts were considered abundantly available. All the information was recorded in the herbarium sheet or in the field workbook and the medicinal plant information was entered in the Microsoft Excel sheet for data synthesis and analysis. The analysis was grouped into six categories: family diversity; life forms; Gewog-wise plant distribution; altitude; plant status; and the parts used. All the medicinal plants identified in the present study were tabulated (Table 1) and the BSM name (written in transliteration), botanical name, local name, family, part used, ethnomedical uses, and the reported pharmacological activities were recorded against each species.

### 3. Results

#### 3.1. LAMP diversity of Lower Kheng Region

We have botanically identified a total of 61 LAMP from the subtropical region of Lower Kheng. Table 1 presents their botanical
# Table 1 – List of identified low-altitude medicinal plant species in Lower Kheng region.

| Botanical name and Family | Sowa Rigma name | Local name (Khengkha) | Life form | Status | Part used | Sowa Rigma uses | Ethnopharmacologically relevant biological activities |
|---------------------------|-----------------|------------------------|-----------|--------|-----------|----------------|---------------------------------------------|
| Abelmoschus manihot (Malvaceae) | so-ma-ra-d.za | Dong-dong-ma | Shrub | Av | Seed | Leprosy, skin disorders, rheumatism, and gout | Anti-ulcer, antibacterial, and anti-inflammatory |
| Aquillaria malaccensis (Thymelaeaceae) | a-ga-ru | Aga-ru | Tree | Ab | Heart wood | Useful for nervous system disorders, nerve, sedative, and refrigerant for heart disorder | Antimicrobial, anesthetic, analgesic, and positive effect on central nervous system |
| Aristolochia griffithii (Aristolochiaceae) | ba-le-ka | Ruu-shing | Climber | Ab | Stem | Febrifuge, anodyne and analgesic for blood disorders, blood purifier, sepsis, and cough | Antimalarial (associated with fever and blood) |
| Asparagus racemosus (Asparagaceae) | nyi-shing | Nala-khang-chung | Woody vine | Av | Root | Antiaging, defective air related disorders, pathogenic serum, anti-inflammatory | Antioxidant, antiulcer, antibacterial |
| Beaumontia grandiflora (Apocynaceae) | dug-mo-nyung | Ne-uai-num-phang | Woody vine | Ab | Seed | Antitoxin, anthelmintic and vermifuge, defective bile related disorders, poisoning, and diarrhea | Antioxidant |
| Bombax ceiba (Malvaceae) | pad-ma-ge-sar | Pema-ghey-ser | Tree | Ab | Flower | Cardiac tonic and febrifuge for heart disorders | Extracts and compounds showed hepatoprotective, antiangiogenic, hypotensive, and hypoglycemic |
| Brassica juncea (Brassicaceae) | yung-d.kar | Yung-kar | Herb | Ab | Seed | Aphrodisiac, antitoxin, antiseptic, defective serum related diseases, and evil spirit afflictions | Antioxidant |
| Brassica rapa (Brassicaceae) | nung-ma | Ya-ua | Herb | Av | Root | Antidote and vitality regeneration | Antioxidant, antimicrobial, and antiabetic activities |
| Buddleja bhutanica (Scrophulariaceae) | chang-rtsi | Phab-seng | Shrub | Ab | Leaf | Dyspepsia, nerve, and regenerates nerves; used for preparing yeast | Not tested |
| Butea parviflora (Fabaceae) | ma-ru-rtse | Rongkalee-zeewa | Shrub | R | Seed | Anthelmintic, vermifuge, antibacterial, eupeptic, and digestive | Antifungal |
| Canarium strictum (Burseraceae) | spos-d.kar | Po-kar | Tree | R | Oleoresin | Serum related disorders (chu-ser-nad), defective air related disorders (rlung-nad), swollen and inflamed testicles (rlig-rlugs); also used in incense | Anti-inflammatory and antimicrobial |
| Capsicum annuum (Solanaceae) | tsi-tra-ka | Bang-ga-la | Herb | Ab | Fruit | Antibacterial and leprosy, digestive, and piles | Antibacterial, antioxidant, anti-inflammatory |
| Botanical name and Family | Sowa Rigpa name | Local name (Khengkha) | Life form | Status | Part used | Sowa Rigpa uses | Ethnopharmacologically relevant biological activities |
|---------------------------|-----------------|------------------------|-----------|--------|-----------|-----------------|-----------------------------------------------------|
| Cassia tora (Fabaceae)    | thal-ka-rdo-rje | She-leg-pa | Herb | Ab    | Seed | Aphrodisiac, ringworm, wounds, abscess, skin irritation, ultraviolet rays, vertigo, body tremor, facial deformities, and paralysis | Immunostimulatory activity, antioxidant, antifungal, antibacterial, wound healing, anti-inflammatory, analgesic, and hepatoprotective |
| Cautleya spicata (Zingiberaceae) | sga-skya | Dang-ko-ma | Herb | R     | Rhizome | Anticoagulant, attenuant, febrifuge, defective phlegm and air related disorders (bad-rlung) | Antibacterial, antifungal, antiprotozoal, antifertility and anti-inflammatory |
| Chorospondias axillaris (Anacardiaceae) | sning-zho-sha | Kru-ta-lee | Tree | Av    | Fruit | Febrifuge, cardiac tonic, drowsiness, tongue infection, chest pain, appetite, dehydration, and calming | Antioxidant and anti-angiogenic |
| Cinnamomum granduliferum (Lauraceae) | a-gar-go-snöd | Unknown | Tree | Av    | Wood | Diarrhea, carminative, flatulence, and lung infection (glo-nag) | Antimicrobial and anticancer |
| Cinnamomum impressinervium (Lauraceae) | shing-tsa | Chin-chang | Tree | Av    | Bark | Antidiabetic |
| Coriandrum sativum (Apiaceae) | hu-su | Hon-su | Herb | Ab    | Seed | Lithontripic and defective phlegm disorders | Antimicrobial, antioxidant, anxiolytic, analgesic, anti-inflammatory, hypoglycemic, hypolipidemic, and antitumor activities |
| Curcuma longa (Zingiberaceae) | yung-ba | Yong-ket | Herb | Ab    | Rhizome | Tonic, inflammation, sepsis, and preservative | Anti-inflammatory, antioxidant, antimicrobial, and nematocidal activities |
| Drynaria propinqua (Polypodiaceae) | re-rel | Kha-ri-shog-pa | Epiphytic | Av    | Stem | Antidote, detoxifier, and poisoning (sbyar-dug) | Antioxidant |
| Entada rheedi (Fabaceae) | m.chin-pa-zho-sha | Yang-ka-lee | Climber | Av    | Seed | Detoxifier and useful for liver poisoning (m.chin-dug), neuralgia, paralysis and other nerve related disorders | Antiproliferative and antioxidant |
| Erythrina arborescens (Fabaceae) | m.khal-ma-zho-sha-nag-po | Dong-leng-ma-seng | Tree | Ab    | Seed | Febrifuge for kidney disorders, urine infection, back pain, giddiness, and disabilities | Hypotensive, cytotoxic |
| Fraxinus paxiana (Oleaceae) | stabs-seng | Sib-shing | Tree | Av    | Bark | Bone fracture and infection, eye disorders, and vulcanery | Antispasmodic and uterine stimulant |
| Gossypium hirsutum (Malvaceae) | re-bras | Kam-phai | Shrub | Av    | Seed | Antiepistaxis and nose disorders | Not tested |
| Scientific Name | Common Name | Family | Part Used | Form | Functions |
|-----------------|-------------|--------|-----------|------|-----------|
| Jatropha curcas  | Dan-rog     | Euphorbiaceae | Shrub | Ab | Seed | Furtive, laxative, and undoing constipation |
| Juglans regia   | Star-ga     | Juglandaceae | Tree | R  | Nut  | Defective air related disorders (rlung-nad) and stiffness of limbs |
| Justice adhatoda| Khor-ga-sha-ka-dkar-po | Acanthaceae | Shrub | Ab | Leaf | Febrifuge, blood disorders, blood pressure (khrag-g.zir), anodyne, liver, and bile infections |
| Knema tenuinervia| Du-ru-ka    | Myristicaceae | Tree | Ab | Heart Wood | Heart disorders, fever, drowsiness, tongue disorder, chest pain, appetizer, calming, and defective air-related disorders (rlung-nad) |
| Lagenaria siceraria| Ka-bed     | Cucurbitaceae | Climber | Ab | Seed | Diarrhea and dysentery |
| Luffa aegyptiaca| G.ser-gyi-phud-bu | Cucurbitaceae | Climber | Ab | Seed | Emetic, detoxifier, and jaundice |
| Mangifera indica| Am-bras     | Anacardiaceae | Tree | Av | Seed | Kidney disorders, and rejuvenator |
| Millettia pachycarpa| A-bras | Fabaceae | Woody vine | Av | Seed | Kidney disorders |
| Morus macroura  | Seng-leng   | Moraceae | Tree | Ab | Wood | Blood purifier, defective blood and serum, wounds, and abscess |
| Mucuna imbricata| Gla-gor-zho-sha | Fabaceae | Climber | Av | Seed | Febrifuge, spleen disorders, mouth and tongue related diseases, knee swelling, backache, numbness, and tingling sensation |
| Oroxylum indicum| Tsam-pa-ka-me-tog | Bignoniaceae | Tree | Ab | Seed | Febrifuge and antimalarial |
| Oryza sativa    | 'bras       | Poaceae | Grass | Ab | Seed | Diarrhea, anti-emetic, demulcent, adaptogen, relaxant, aphrodisiac, restores youthfulness, and disorders originating from air, bile and phlegm |
|                |             |         |         |     |       | Anti-inflammatory, analgesic, and antimicrobial activity |
|                |             |         |         |     |       | Keratolytic, antifungal, hypoglycaemic, hypotensive, and sedative activities |
|                |             |         |         |     |       | Antitissive, hepatoprotective cardioprotective, anti-inflammatory, antimicrobial and muscle relaxant |
|                |             |         |         |     |       | Not tested |
| Botanical name and Family | Sowa Rigpa name | Local name (Khengkha) | Life form | Status | Part used | Sowa Rigpa uses | Ethnopharmacologically relevant biological activities |
|---------------------------|-----------------|------------------------|-----------|--------|-----------|----------------|-------------------------------------------------|
| Otochilus lancilabius (Orchidaceae) | pu-shel-rtsae | Agar-mentog | Epiphytic | Av | Stem | Antiemetic, febrifuge for stomach inflammation (bad-tshad), and allays hyperdipsia and dehydration. Febrifuge, blood infection (khrag-tshad), painful blood pressure (khrag-g.zir), liver inflammation (m.chin-tshad), and bile disorders (m.khris-tshad) | Not tested |
| Phlogacanthus thyrsiformis (Acanthaceae) | khrog-ba-sha-ka-d.mar-po | Plum-seng-ma | Shrub | Av | Leaf | Febrifuge, defective phlegm, and bile (bad-m.khris) disorders | Analgesic, anti-inflammatory, and antioxidant activities |
| Phyllanthus emblica (Phyllanthaceae) | skyu-ru | Plut-ching-ka | Shrub | Ab | Fruit | Antimicrobial, anti-oxidant, anti-inflammatory, hepatoprotective, antitissuive, immunomodulatory, hypolipidemic, anticancer, anti-diabetic, and wound healing activities | Antiplatelet aggregation and insecticide |
| Piper mullesua (Piperaceae) | pi-pi-ling | Bar-dum-za-lu | Shrub | Ab | Fruit | Aphrodisiac, flatulence, asthma, digestive, hematinic, blood purifier, rejuvenates kidney, dry cough, backache, abdominal pain, urine infection, and swollen testes | Not tested |
| Quercus griffithii (Fagaceae) | mon-cha-ra | Pe-seng | Tree | Ab | Nut | Gastrointestinal, throat and lung infections, and antiasthma | Gastrointestinal stimulation and gut protective effects, antioxidant, antibacterial, hepatoprotective, immuno-modulatory, and cholesterol lowering |
| Raphanus sativus (Brassicaceae) | la-phug | Ya-va | Herb | Ab | Root | Purgative, emetic, appetizer, asthma, and lung rejuvenator | Antioxidant, anticancer, antiviral, antimicrobial, anti-diarrheal, anti-inflammatory, and antithrombin activities |
| Rhus chinensis (Anacardiaceae) | da-trig | Blam-dung | Tree | Ab | Fruit | | |
| Ricinus communis (Euphorbiaceae) | dan-khra | Cha-me-la | Shrub | Ab | Seed | | |
| Rubia manjith (Rubiaceae) | b.tsod | Tshud | Climber | Av | Stem | Hematinc, blood disorders, and debilitating chronic fever | |

Notes: 2-22
| Scientific Name                      | Common Name      | Plant Part | Part Used | Uses                                                                 | Additional Properties                                                                 |
|-------------------------------------|------------------|------------|-----------|----------------------------------------------------------------------|---------------------------------------------------------------------------------------|
| Rubus ellipticus (Rosaceae)         | ga-bra           | Shrub      | Av        | Bark                                                                | Cough and cold and blood disorders (rlung-khrag)                                     |
| Saccharum officinarum (Poaceae)     | bur-shing        | Grass      | Ab        | Stem                                                                | Analgesic, hyperdipsia and dehydration, nausea, vertigo, fainting, and bile disorder |
| Sapindus rarak (Sapindaceae)        | po-so-cha        | Tree       | Av        | Fruit                                                               | Emetic; local people use it as shampoos for head lice                                |
| Selaginella involvens (Selaginellaceae) | sngo-chu-sder-mo | Grass      | R         | Leaf                                                                | Dropsy, bone fracture and stiffness of limbs                                        |
| Sesamum indicum (Pedaliaceae)       | til-d.kar        | Herb       | Ab        | Seed                                                                | Nourishes and replenishes body, defective air related disorders, and improves sperm  |
| Stephania glabra (Menispermaceae)   | d.po'-ser-po     | Climber    | R         | Tubber                                                             | Febrifuge for poisoning (dug-tshad)                                                  |
| Symplocos sumantia (Symplocaceae)   | zhu-m.khan       | Shrub      | R         | Leaf                                                                | Febrifuge for chronic lung infection and kidney diseases ('gram-tshad)                 |
| Syzygium cumini (Myrtaceae)         | sra-'bras        | Tree       | Av        | Fruit                                                               | Replenishes kidney and heals kidney disorders                                         |
| Terminalia bellirica (Combretaceae) | ba-ru            | Tree       | Av        | Fruit                                                               | Cholagogue, hydragogue, gout, arthritis, leprosy (chu-ser-nag-po), defective bile (bad-m.khris) disorders, and for hair loss |
| Terminalia chebula (Combretaceae)   | a-ru             | Tree       | Av        | Fruit                                                               | Restore three defective humors and bodily constituents, anti-dysenteric, anti-diarrheal, chronic lung and kidney infections, and cough and cold |

Not tested: 75
Antioxidant and antiatherogenic: 76
| Botanical name and Family | Sowa Rigpa name | Local name (Khengkha) | Life form | Status | Part used | Sowa Rigpa uses | Ethnopharmacologically relevant biological activities |
|--------------------------|-----------------|-----------------------|-----------|--------|-----------|-----------------|-----------------------------------------------------|
| *Thysanolaena latifolia* (Poaceae) | rtsa-ku-sha | Phig-shang | Grass | Ab | Flower | Antiaging, nourishes body and increases longevity | Chemopreventative, antioxidant and hepatoprotective |
| *Tinospora cordifolia* (Menispermaceae) | sle-tres | Zhim-pleng-ma | Climber | Av | Stem | Febrifuge for air disorders (rlung-tshad) and severe pain due to te bone disorders (rlung-rims) | Anti-inflammatory, antiallergic, antidiabetic, hepatoprotective, antioxidant, antimicrobial, renoprotective, gastroprotective, and chemopreventive |
| *Triticum aestivum* (Poaceae) | dro | Kar | Grass | Av | Seed | Aphrodisiac, nourishes body and defective air and bile (rlung-m.khris) related disorders | Antioxidant, antiarthritic, antiful, and anticancer activities |
| *Xanthium indicum* (Asteraceae) | byi-tsher | Ra-ua | Herb | Av | Fruit | Febrifuge, cold and flu, poisoning (lug-tshad), kidney disorders (m.khel-tshad), and air-related disorders | Antitussive, antibacterial, antifungal, antitumor, anticancer, anti-inflammatory, antiparasitic, and antioxidant |
| *Zanthoxylum armatum* (Rutaceae) | g.yer-ma | Cha-ua | Shrub | Ab | Fruit | Antimicrobial, vasodilator, dermatological diseases, dispels alcohol hangover, food poisoning, indigestion, and progresses melodious voice | Antimicrobial, antiparasitic, hepatoprotective, anti-inflammatory, and keratocytoc inhibitor |
| *Zingiber officinale* (Zingiberaceae) | sman-sga | Ka-chag-pa | Herb | Ab | Rhizome | Antimicrobial, appetizer restores bodily heat, spleen infection (m.cher-tshad), defective air and phlegm (bad-rlung) disorders, cold disorders and the lower abdominal parts infections including urinary tract (grang-rlung) | Antimicrobial, antioxidant, anti-inflammatory, analgesic, beneficial gastrointestinal effects, anticancer, pancreatic cancer, antiemetic, antidepressant, and temperature regulation |

Ab, abundant; Av, available; R, Rare.
name, BSM (vernacular) name, local community (Khengkha) name, prevalent life form, availability status, part used in BSM, and the BSM uses (translated from the traditional texts and pharmacopoeia). These 61 LAMP belong to 58 genera and 40 different families (Table 2).

3.2. Availability status of medicinal plants

Out of 61 LAMP, 30 species were found in abundance, 24 species in moderation and only 7 species were identified as rare (Fig. 2). Terminalia chebula (Aru), Terminalia bellirica (Baru), and Phyllanthus emblica (chur), which are locally considered “King of Medicine” (Mengo-Pauo) or “Three Powerful Medicines”, were all found growing in moderation or abundantly in all the three Gewogs. Aquilaria malaccensis, which is considered as rare species in other parts of the world, is abundantly cultivated in the household or community gardens of all the three Gewogs in Lower Kheng. Canarium strictum, which is locally used as incense is, however, a rare species in the region.

| Family               | No. of plant species | Family               | No. of plant species |
|----------------------|----------------------|----------------------|----------------------|
| Acanthaceae          | 2                    | Moraceae             | 1                    |
| Anacardiaceae        | 3                    | Myristicaceae        | 1                    |
| Apiceae              | 1                    | Myrtaceae            | 1                    |
| Apocynaceae          | 1                    | Oleaceae             | 1                    |
| Aristolochiaceae     | 1                    | Orchidaceae          | 1                    |
| Asparagaceae         | 1                    | Pedaliaceae          | 1                    |
| Asteraceae           | 1                    | Phyllanthaceae       | 1                    |
| Bignoniaceae         | 1                    | Piperaceae           | 1                    |
| Brassicaceae         | 3                    | Poaceae              | 4                    |
| Burseraceae          | 1                    | Polypodiaceae        | 1                    |
| Combretaceae         | 2                    | Rosaceae             | 1                    |
| Cucurbitaceae        | 2                    | Rubiaceae            | 1                    |
| Euphorbiaceae        | 2                    | Rutaceae             | 1                    |
| Fabaceae             | 5                    | Sapindaceae          | 1                    |
| Fagaceae             | 1                    | Scrophulariaceae     | 1                    |
| Juglandaceae         | 1                    | Selaginellaceae      | 1                    |
| Lauraceae            | 2                    | Solanaceae           | 1                    |
| Leguminosae          | 1                    | Symlocosaceae        | 1                    |
| Malvacaceae          | 3                    | Thymelaeaceae        | 1                    |
| Menispermaceae       | 2                    | Zingiberaceae        | 3                    |

3.3. Variety of life forms or habits of medicinal plants

The 61 LAMP that we have identified from the study areas, fell within seven habit groups (Fig. 3). Fig. 3 represents life forms as trees (Fig. 3A), shrubs (Fig. 3B), herbs (Fig. 3C), grasses (Fig. 3D), woody vines (Fig. 3E), climbers (Fig. 3F), and epiphytes (Fig. 3G). The distribution of medicinal plants against each life form is represented in Fig. 3H. Majority of the medicinal plants (19 species) were trees, followed by shrubs (13 species), and then herbs (11 species). Although, many epiphytic plants including mistletoes were spotted during the survey, only two species—which is the lowest among the category of life-forms—were used as medicinal plants. This study identified Phlogacanthus thrysiformis (Krogbasha-ka-marpo) (Fig. 3B) as a medicinal plant for the first time. The description of this plant can be found in the ancient traditional text but it is currently not used in the BSM formulation.

3.4. Segregation by usage of the plant parts

The plant parts that can be collected for using in BSM includes wood, tuber, stem, seed, root, rhizome, oleoresin, nut, leaf, heartwood, fruit, flower, and bark, with majority being the seed (Fig. 4). Of 61 species botanically identified in total, 20 of them can be used for their seeds, 11 for their fruits, six for their stems, and five for their leaves. Tuber and oleoresin were the least collected parts with only one species each.

3.5. Distribution of LAMP by elevations of three Gewogs of Lower Kheng

All 61 LAMP that were identified from three Gewogs were found to grow in the subtropical zone within an altitude range of 100–1800 masl. Among the three Gewogs surveyed, Goshing Gewog was found to host maximum number of medicinal plants with 40.9% of the total 61 species identified, which is followed by Mangphkar Gewog with 31.1% and Ngangla with 28% (Fig. 5). More than 20 medicinal plants species, including Phyllanthus emblica, Tinospora cordifolia, Cassia tora, Phlogacanthus thrysiformis, Justicia adhatoda, Cauleya spicata, Stephania glabra, Canarium strictum, Otochilus lancicabius, Piper mullusca, Bombyx ceiba, Erythrina arborensis, Khema tenuinerva, Rhus chinensis, Cinnamomum impressinervium, Aquilaria malaccensis, Symlocos sumuntia, Mucuna imbricata, Terminalia chebula, and Chaerophydioides axillaris, were found in all three Gewogs surveyed.

3.6. Edible and socioculturally important LAMP of Lower Kheng

Interestingly, about 28 species of LAMP identified here are also consumed by the three Gewog communities as fruits, vegetables, seeds, food grains, herbs, and spices. About 17 species of these edible medicinal plants are cultivated in the household gardens or farms. The medicinal plants consumed by the three Gewog communities as food grains, herbs, spices, vegetables, fruits and nuts are: Oryza sativa, Triticum aestivum, Capsicum annum, Zanthoxylum armatum, Zingiber officinale, Brassica rapa, Brassica juncea, Coriandrum sativum, Sesamum indicum, Mangifera indica, Juglans regia, Saccharum officinarum, Asparagus racemosus, and Curcuma longa. The medicinal plants
consumed by the local communities as wild fruits, vegetables and roots are: Justicia adhatoda, Rhus chinensis, Entada rheedii, Choerospondias axillaris, Terminalia chebula, Terminalia bellirica, Phyllanthus emblica, Rubus ellipticus, Rhus chinensis, Piper mullesua, and Cinnamomum impressinervium. Entada rheedii (Yangkali) and wild yams form the staple food of the communities during famines.

We also found that the local communities use Canarium strictum and Aquillaria malaccensis as incense for rituals and religious offerings. Buddleja bhutanica, is used for making yeast for brewing local alcohol called Bangchang and Ara (similar to Korean Soju). Rubia manjith is locally used as dye for clothing made from Gossypium hirsutum (cotton, also used as medicinal plants). The communities use Luffa aegyptiaca, Lagenaria siceraria, and Sapindus rarak as cleansing agents.

Fig. 3 – Low-altitude medicinal plants representing seven different life forms (courtesy: P.W collection). (A) Aquillaria malaccensis represents a tree life form. (B) Phlogacanthus thyrsiformis represents a shrub life form. (C) Xanthium indicum represents a vine life form. (D) Thysanolaena latifolia represents a grass life form. (E) Beaumontia grandiflora represents a woody vine. (F) Entada rheedii represents a shrub life form. (G) Drynaria propingua represents an epiphytic form. (H) Graph showing number of species against each life form.
3.7. Reported pharmacological activities of LAMP

Data mining of 61 species for their reported pharmacological activities revealed that 52 of them have been already subjected to scientific validation of their ethnopharmacological uses. Either their crude extracts or pure isolated compounds have shown various pharmacological activities as listed in Table 1. Most of the scientific studies involving biological activity screening were conducted outside Bhutan specifically targeting Indian Ayurvedic medicinal plants. However, nine of them remain unstudied for their biological activities.

4. Discussion

Goshing, Ngangla, and Phangkar Gewogs together have the total land area of 84,142 hectares (ha) with 76,795 ha under tree cover, 2434 ha under shrubs, 897 ha under meadows, and 1104 ha under water bodies.83 About 76.9% of these lands lie in the subtropical geographical zone (100–1800 masl, 17.2–23.6 °C annual mean temperature, 850–5500 mm rainfall per annum) and 23% lie under warm temperate zone (1800–2600 masl, 12.5 °C annual mean temperature, 650–850 mm rainfall per annum).83,84 The heavy rainfall feeds the region’s two big rivers, Mangdechu and Drangmechu, which join together at Tungudemba (Ngangla Gewog) to form the country’s largest river (Manas River). This river system supports the lush subtropical flora, fauna, and medicinal plants of the region. All 61 LAMP that were identified from three Gewogs were found to grow in the subtropical zone within an altitude range of 100–1800 masl. Among three Gewogs, Goshing hosted largest number of medicinal plants species.

Since the pressure on medicinal plants growing in Langthel region had been increasing due to persistent collection for more than 48 years, this finding provide basis for the MSP to establish an alternative collection center (with a drying facility) at Goshing Gewog. Goshing Gewog falls in the center of other two Gewogs (Phangkhar and Ngangla) and it is easily accessible by motor roads. Establishing an alternative collection center in Lower Kheng region has numerous benefits. First, Lower Kheng communities could generate decent income through a medicinal plant collection program and improve their socioeconomic status. Second, the MSP could obtain sustainable supply of subtropical medicinal plants to meet the demand of Sowa Rigpa medicine production, which is increasing every year. Third, training on sustainable collection of medicinal plants would educate Lower Kheng farmers on the values, protection, and preservation of plants. Fifth, establishing this alternative collection center would reduce the pressure on Langthel medicinal plants population and could enable MSP to collect the plants on a rotational basis allowing the collection sites to regenerate healthy medicinal plants population.

Of 61 LAMP, 30 species were found growing abundantly in the study areas and we have identified Phlogacanthus thrysiformis (Krog-basha-ka-marpa; Fig. 3B) as a medicinal plant from this region for the first time in Bhutan. While we saw MSP as the immediate consumer for these subtropical medicinal plants, some plants also have international significance especially to the countries that practice Sowa Rigpa including India, Nepal, Mongolia, Tibet, Europe, and North America. For example, Aquilaria malaccensis, Piper mullesua, Phyllanthus emblica, Terminalia chebula, and Terminalia bellirica are widely used in these countries especially in India and therefore present huge marketing potential. Aquilaria malaccensis, which is considered a rare species in other parts of the world, is abundantly cultivated in the household or community gardens of all the three Gewogs in Lower Kheng. Medicinal plants used in BSM also played significant role in the sociocultural settings of the communities in the region. Twenty-eight medicinal plants, including 17 cultivated species were either consumed as fruits, vegetables, seeds, nuts, roots, food grains, herbs, and spices. Canarium strictum and Aquilaria malaccensis are used as incense for rituals, religious offerings, and cleansing ceremonies. While the locally brewed alcohol (Bangchang and Ara) uses Buddleja bhutanica as yeast ingredient, Rubia manjith is used for dyeing clothing made from Gossypium hirsutum. Luffa aegyptiaca, Lagena siceraria, and Sapindus rarak forms the household items for health and sanitation.

Data mining or literature review on all 61 species of medicinal plants for their reported pharmacological activities revealed that 52 of them have been already subjected to scientific studies and only eight species remained unstudied (Table 1).23-82 Most of the LAMP grow in the temperate, subtropical and tropical agroclimatic regions and are distributed
worldwide. Consequently, same or similar medicinal plants are found common in traditional medicines practiced in the Asia–Pacific and African countries, although they may be used for treating different ailments in different countries. For that reason, most of the LAMP have been found previously studied for their phytochemical and pharmacological activities with most studies reported by Indian and Chinese scholars on Indian and Chinese medicinal plants. However, there is no single scientific literature on the Bhutanese grown LAMP, which are used in BSM. Plant qualities, phytoconstituents and their pharmacological activities varies from region to region depending upon their habitat and environmental conditions. Therefore, medicinal plants growing in Bhutan may have different phytoconstituents and therapeutic effects, which call for robust scientific validation studies.

While Table 1 shows the reported biological/pharmacological activities of each plant, it must be noted here that those studies were performed to validate the ethnopharmacological uses of other traditional medical system and not of BSM or TSM. In investigating any medicinal plants for their pharmacological activities, it is crucial to have in-depth understanding of the incumbent traditional pharmacopoeias under examination, which would enable researchers to design an appropriate and ethnopharmacologically relevant bioassay protocols. For example, plants whose traditional uses were indicated for treating leprosy, tuberculosis, and wounds can be directed for antimicrobial screening bioassays. Whether the ethnopharmacological uses or indications of each plant were analyzed to determine the appropriate bioassay targets, or whether the complex and difficult-to-understand diseases were dissected into signs and symptoms to compare with the Western medical diseases were not clear in many of the reported literature cited in Table 1. Most of the literature lacked proper experimental design and the quality of the journals are questionable. Nevertheless, these scientific studies provide important information that could guide future phytochemical and pharmacological works on medicinal plants used in BSM and TSM.

### 5. Conclusions and future direction

We have traditionally and botanically identified 61 medicinal plants for the first time from the subtropical zone (altitude range of 100–1800 masl) of Bhutan and 30 of them were found in abundance. We also found that 17 of these medicinal plant species are cultivated either as food grains, vegetables, spices, or fruits. Goshing Gewog had the highest number of medicinal plants species and therefore found suitable for establishing an alternative collection centre (with drying facilities) for MSP. Seeds are the most commonly used LAMP parts in BSM.

Many plant species have commercial and economic values. While MSP is currently viewed as the sole domestic market for these medicinal plants, many species have international significance (especially applicable to countries that practice Tibetan Soua Rigpa medicine and Indian Ayurvedic medicine including India, Nepal, Mongolia, Tibet, Europe, and Northern America). The communities would largely benefit by domesticating or cultivating them in the household gardens or as cash crops in their family orchards. This medicinal plants program has the potential to alleviate poverty in these three Gewog communities and could enhance the happiness, wellbeing and development in Bhutan. Since the communities consume 28 medicinal plants as food grains, spices, herbs, and fruits, it can be assumed that the local people are also deriving health benefits.

In future, we recommend the following works, which could be initiated by the Ministry of Health in Bhutan: (1) educate and train farmers on the sustainable management and harvesting of wild subtropical medicinal plants; (2) conduct value chain analysis and identify risk factors for the use of wild species of medicinal plants identified through this survey; (3) develop a sustainable management plan for the subtropical medicinal plants; (4) perform domestication of wild species and cultivation trials; (5) extend similar medicinal plants surveys and botanical identification to other parts of the country using same protocols described here or in our earlier studies; and (6) initiate biodiscovery and value addition on the subtropical medicinal plants using the approaches described.

All these findings could help the MSP and the farmers to strategically lay road map for medicinal plants domestication, diversification of herbal products, and their commercialization.

### Conflicts of interest

The authors declare that they have no competing interests.

### Ethics approval and consent to participate

Traditional Medicine Research and Development Committee of Bhutan (TMRDC) approved this study. Ethical and informed consent to survey the research sites were obtained from the respective Gewog gups.

### Funding

The World Health Organization (WHO) supported this study. However, it had no role in the design of the study and collection, analysis, and interpretation of data and in writing the manuscript.

### Authors’ contributions

KJ lead the field work team to three Gewogs and carried out the field survey and plant identification. KY assisted in gathering general information on plant identification. PW designed and conceptualized the study, botanically identified the medicinal plant, translated the plant uses in to English, conducted pharmacological activity data mining, supervised and edited the survey report, and wrote the manuscript. All authors read and approved the final manuscript.
Acknowledgments

We are grateful to the following: World Health Organization for funding the field survey and the MSP for delegating and approving this important study. Gups (Gewog/local leader) of three Gewogs for arranging the horses and the local informant. Drungtshe Karma Gayleg, Mrs Tsherling Zam, Mrs Norbu Drolma, Senior Menpa Jigme Thinley, and Mr Samten of MSP for their assistance during the field work. The inhabitants of our study sites: Phangkhar, Goshing, and Ngangla Gewogs for their hospitality and welcoming us in their houses.

REFERENCES

1. Wangchuk P, Tobgay T. Contributions of medicinal plants to the Gross National Happiness and Biodiscovery in Bhutan. J Ethnobiol Ethnomed 2015;11:48.
2. Gewali MB. Aspects of traditional medicine in Nepal. Toyama: Institute of Natural Medicine. 2008.
3. Tibetan medicine history. Men-Tsee-Khang (Soua-Rig-pa). Dharamsala: Tibetan Medical and Astro-science Institute; 2016.
4. Wangchuk P, Pyne SG, Keller PA. An assessment of the Bhutanese traditional medicine for its ethnopharmacology, ethnobotany and ethnoquality: textual understanding and the current practices. J Ethnopharmacol 2013;148:305–10.
5. Tenzin S. Traditional Medicine Formulary of Bhutan. Thimphu: Pharmaceutical and Research Unit, Institute of Traditional Medical Services, Department of Medical Services, Ministry of Health, 2007.
6. Wangchuk P, Namgay K, Gayleg K, Dorji Y. Medicinal plants of Dagala region in Bhutan: their diversity, distribution, uses and economic potential. J Ethnobiol Ethnomed 2016;12:28.
7. Wangchuk P, Pyne SG, Keller PA. Ethnobotanical authentication and identification of Khrog-sman (Lower Elevation Medicinal Plants) of Bhutan. J Ethnobiol Ethnomed 2011;134:813–23.
8. Phuntshok DT. Shel-gong-Shel-Phreng. India: TMAI Publishers; 1994.
9. Grierson AJC, Long DG. Flora of Bhutan: including a record of plants from Sikkim, Vol. 1 Part 1. Edinburgh: Royal Botanic Garden; 1983.
10. Grierson AJC, Long DG. Flora of Bhutan: including a record of plants from Sikkim, Vol. 1 Part 2. Edinburgh: Royal Botanic Garden; 1984.
11. Grierson AJC, Long DG. Flora of Bhutan: including a record of plants from Sikhim, Vol. 1 Part 3. Edinburgh: Royal Botanic Garden; 1987.
12. Grierson AJC, Long DG. Flora of Bhutan, Vol. 2 Part 1. Edinburgh: Royal Botanic Garden; 1991.
13. Grierson AJC, Long DG. Flora of Bhutan, Vol. 2 Part 2. Edinburgh: Royal Botanic Garden; 1999.
14. Grierson AJC, Long DG. Flora of Bhutan, Vol. 2 Part 3. Edinburgh: Royal Botanic Garden; 2001.
15. Naithani HB. Flowering plants of India, Nepal and Bhutan (not recorded in Sir J.D. Hooker’s Flora of British India). Debra Dun: Surya Publications; 1990.
16. Nolitie HJ. Flora of Bhutan: including a record of plants from Sikkim and Darjeeling. Vol. 3 Part 1. Edinburgh: Royal Botanic Garden; 1994.
17. Nolitie HJ. Flora of Bhutan. Vol. 3 Part 2. Edinburgh: Royal Botanic Garden; 2000.
18. Polunin O, Stainton A. Flowers of the Himalaya. Oxford: Oxford University Press; 1997.
19. Pandey G. Medicinal plants of Himalaya. Delhi: Sri Satguru Publications, Indological and Oriental Publishers; 2000.
20. The Plant List; 2013. Version 1.1. [http://www.theplantlist.org/]. Accessed February 21, 2016.
21. eFloras.org. Flora of China; 2008 [http://www.efloras.org], Accessed February 21, 2016.
22. Tropicos.org. Missouri Botanical Garden; 2016 [http://www.tropicos.org]. Accessed May 11, 2016.
23. Zhang HY, Dong LY, Jiang Q, Fang M, Li JP, Chen ZW, et al. Effect of anti-infection oral mucosa ulcers of guinea-pig and antibacterial in vitro of total flavone of Abelmoschus manihot (L.) Medic. Anhui Med Pharm J 2006;10:810–1.
24. Jain PS, Bari SB. Anti-inflammatory activity of Abelmoschus manihot extracts. Int J Pharmcol 2010;6(4):505–9.
25. Okugawa H, Ueda R, Matsumoto K, Kawanishi K, Kato A. Effects of agarwood extracts on the central nervous system. Planta Med 1993;59:32–6.
26. Gunasekera SP, Kinghorn AD, Cordell GA, Farnsworth NR. Plant anticancer agents XIX. Constituents of Aquilaria malaccensis. J Nat Prod 1981;44:569–72.
27. Chen HQ, Wei JH, Yang JS, Zhang Z, Yang Y, Gao ZH, et al. Chemical constituents of agarwood originating from the endemic genus Aquilaria plants. Chem Biodivers 2012;9:236–50.
28. Das NG, Rabha B, Talukdar PK, Goswami D, Dhma S. Preliminary in vitro antiplasmodial activity of Aristolochia griffithii and Thalictrum foliolosum DC. extracts against malaria parasite Plasmodium falciparum. BMC Res Notes 2016;9:51.
29. Sairam K, Priyambada S, Aryna NC, Geol RK. Gastroduodenal ulcer protective activity of Asparagus racemosus: an experimental, biochemical and histological study. J Ethnopharmacol 2003;86:1–10.
30. Bopana N, Saxena S. Asparagus racemosus—Ethnopharmacological evaluation and conservation needs. J Ethnopharmacol 2007;110:1–15.
31. Abdelshafeek KA, Abou-Seta L, Nazif NM. Study of some chemical constituents and antioxidant activity of Beaumontia grandiflora Wall grown in Egypt. Aust J Basic Appl Sci 2010;4:1063–9.
32. You YJ, Nam NH, Kim Y, Bae KH, Ahn BZ. Antiangiogenic activity of an extract of Bombax ceiba. Phytother Res 2003;17:341–4.
33. Saleem R, Ahmad M, Hussain SA, Qazi AM, Ahmad SI, Qazi MH, et al. Hypotensive, hypoglycaemic and toxicological studies on the flavonol C-glycoside shaminbin from Bombax ceiba. Planta Med 1999;65:331–4.
34. Ravi V, Patel SS, Vermma NK, Dutta D, Saleem TS. Hepatoprotective activity of Bombax ceiba Linn against isoniazid and rifampicin-induced toxicity in experimental rats. Int J Appl Res Nat Prod 2010;3:19–26.
35. Dua A, Chander S, Agrawal A, Mahajan R. Antioxidants from defatted Indian mustard (Brassica juncea) protect biomolecules against in vitro oxidation. Physiol Mol Biol Plants 2014;20:539–43.
36. Saka B, Djouahri A, Djerrad Z, Terfi S, Aberrick S, Sabaou N, et al. Chemical variability and biological activities of Brassica rapa var. napo fixes parts essential oils depending on geographic variation and extraction technique. Chem Biodivers 2017;14:e1600452.
37. Tintu I, Abhilash J, Diplop KV, Augustine A, Haridas M, Sadasivan C. A lecitin from Spatholobus parviflorus inhibits Aspergillus flavus a-amyrase: enzyme kinetics and thermodynamic studies. Chem Biol Drug Des 2014;84:116–22.
38. Muthuswamy R, Senthamari R. Anti-inflammatory activity of essential oil of Canarium strictum Roxb. Iran J Pharm Sci 2013;9:13–21.
39. Suruse PB, Duragkar NJ, Shivhare UD, Bodele SB. Study of antimicrobial activity of Canarium strictum gum resin. Res J Pharmacogn Phytochem 2010;2:435–7.

40. Zimmer AR, Leonardi B, Miron D, Schapoval E, de Oliveira JR, Gomann G. Antioxidant and anti-inflammatory properties of Capsicum baccatum: from traditional use to scientific approach. J Ethnopharmacol 2012;139:228–33.

41. Bacon K, Boyer R, Denbow C, O’Keefe S, Neilson A, Williams R. Antibacterial activity of jalapeno pepper (Capsicum annum var. annuum). Food Sci Nutr 2017;5:730–8.

42. Bhandirge SK, Patel V, Patidari A, Pasi A, Sharma V. An overview on phytochemical and pharmacological profile of Cissus tora Linn. Int J Herb Med 2016;4:50–5.

43. Goel AK, Kuleshreshtha DK, Dubey MP, Rajendran SM. Screening of Indian plants for biological activity: Part XVI. Indian J Exp Biol 2002;40:812–2.

44. Li Q, Wang X, Dai T, Liu C, Li T, McClements DJ, et al. Proanthocyanidins, isolated from Cheerospondias axillaris fruit peels, exhibit potent antioxidant activities in vitro and a novel anti-angiogenic property in vitro and in vivo. J Agric Food Chem 2016;64:3546–56.

45. Taha AM, Eldahshan OA. Chemical characteristics, antimicrobial and cytotoxic activities of the essential oil of Egyptian Cinnamomum glanduliferum Bark. Chem Biodivers 2017;14:160043.

46. Baljiepalii MK, Buru AS, Sakirola R, Pichika MR. Cinnamomum genus: a review on its biological activities. Int J Pharm Sci 2017;9:1–11.

47. Laribi B, Kouki K, Mhamdi M, Bettaieb T, Coriander (Coriandrum sativum L.) and its bioactive constituents. Fitoterapia 2015;103:9–26.

48. Bhat SV, Amin T, Nazir S. Biological activities of turmeric (Curcuma longa Linn.). An overview. BMIR Microbiol 2015;17:1–5.

49. Parajuli S, Pun NT, Parajuli S, Jamarkattel-Pandit N. Anti-oxidative activity, total phenol and flavonoid contents in some selected medicinal plants of Nepal. JHAS 2002;2:27–31.

50. Nzwara LK, Teponbo RB, Tapondjou LA, Verotta L, Liao Z, Graham D, et al. Two new tryptophan derivatives from the seed kernels of Entada rheedei: effects on cell viability and HIV infectivity. Fitoterapia 2013;87:37–42.

51. de Araújo-Júnior JX, de Oliveira MSG, Aquino PGV, Alexandre-Moreira MS, Sant’Ana AEG. A phytochemical and ethnopharmacological review of the genus Erythrina. In phytochemicals — A global perspective of their role in nutrition and health, Rao V, (Ed.). InTech. Available from: http://www.intechopen.com/books/phytochemicals-a-global-perspective-of-their-role-in-nutrition-and-health-a-phytochemical-and-ethnopharmacological-review-of-the-genus-erythrina.

52. Abdelgadir HA, Staden JV. Ethnobotany, ethnopharmacology and toxicity of Jatropha curcas L. (Euphorbiaceae): a review. S Afr J Bot 2013;88:204–18.

53. Moori BN, Khaliha E. Antibacterial activity of the hydro-alcoholic extract of Juglans regia L. stem bark on human bacterial infection. Quarterly Int Archives Health Sci 2015;2:139–43.

54. Dhanikhar S, Kaur R, Ruhli S, Balhara M, Dhanikhar S, Chhillar AK. A review on Justicia adhatoda: a potential source of natural medicine. Afr J Plant Sci 2011;5:620–7.

55. Prajapati RP, Kaliyari M, Parmar SK, Sheth NR. Phytochemical and pharmacological review of Lagenaria siceraria. J Ayurveda Integr Med 2010;1:266–72.

56. Mhyo DH, Mankilik M. Phytochemical screening of some preserved extract of Luffa aegyptiaca (Sponge gourd) leaves sample from northern Nigeria: a short communication. Int J Pharm Sci Res 2014;5:344–5.

57. Parvez GMM. Pharmacological activities of mango (Manifijera indica): a review. J Pharmacogn Phytochem 2016;5:1–7.

58. Harrison JJEK, Danby E, Kingsford-Adasko R, Ishida H. In search of new leads: a closer look at the therapeutic potential of the constituents of Millettia thonningii, Millettia pachycarpa and their structural analogues. Int J Pharm Sci 2011;3:71–81.

59. Anwar F, Kanwal S, Shabir G, Alkharfy KM, Gilani AH. Antioxidant and antimicrobial attributes of different solvent extracts from leaves of four species of mulberry. Int J Pharm 2015;11:757–65.

60. Deka DC, Kumar V, Prasad C, Kumar K, Gogoi BJ, Singh L, et al. Orzyxolum indicum—a medicinal plant of North East India: an overview of its nutritional, remedial, and prophylactic properties. J Appl Pharm Sci 2013;3:S104–12.

61. Walter M, Marchesan E. Phenolic compounds and antioxidant activity of rice. Braz Arch Biol Technol 2011;54:371–7.

62. Das BK, Al-Amin MM, Chowdhury NN, Majumder MF, Uddin MN, Pavel MA. Analgesic, anti-inflammatory, and anti-oxidant activities of Pilocacanthus thysiflorus leaves. J Basic Clin Physiol Pharm 2015;26:153–9.

63. Hassan R, Islam N, Islam R. Phytochemistry, pharmacological activities and traditional uses of Emblica officinalis: a review. Int Curr Pharm J 2016;5:14–21.

64. Strivastava S, Gupta MM, Tripathi KA, Kumar S. 1,3-Benzodioxazole–5-(2,4,8-triene-methyl nanoate) and 1,3-benzodioxazole–5-(2,4,8-triene-isobutylnanoate) from Piper miltiodes. Indian J Chem 2000;39:946–9.

65. Shin T, Ahn M, Kim GO, Park SU. Biological activity of various radish species. Orient Pharm Exp Med 2015;15:105–11.

66. Djakpo O, Yao W. Rhus chinensis and Gallia chinensis—folklore to modern evidence: review. Phytother Res 2010;24:1739–47.

67. Iqbal J, Saab S, Farooq U, Khan A, Bibi I, Suleman S. Anti-oxidant, antimicrobial, and free radical scavenging potential of aerial parts of Periploca aphylla and Ricinus communis. ISRN Pharmacol 2012;1:6, 563267.

68. Shan M, Yu S, Yan H, Chen P, Zhang L, Ding A. A review of the botany, phytochemistry, pharmacology and toxicity of Rubiae Radix et Rhizoma. Molecules 2016;21:1747.

69. Saini R, Dansgkal K, Singh H, Garg V. Antioxidant and antiproliferative activities of phenolics isolated from fruits of Himalayan yellow raspberry (Rubus ellipticus). J Food Sci Technol 2014;51:3369–75.

70. Singh A, Lal UR, Mukhtar HM, Singh PS, Shah G, Dhawan RK. Phytochemical profile of sugarcane and its potential health aspects. Pharmacol Rev 2015;9:45–54.

71. Banerjee RD, Sen SP. Antibiotic activity of Pteridophytes. Econ Bot 1980;34:284–98.

72. Visavadiya NP, Soni B, Dalwadi N. Free radical scavenging and antiatherogenic activities of Sesamum indicum seed extracts in chemical and biological model systems. Food Chem Toxicol 2009;47:2507–15.

73. Hemraj, Upmanyu N, Gupta A, Jindal A, Jalhan S. Pharmacological activities of Stephania glabra, Woodfordia fruticosa and Cissampelos pareira—a review. Int J Pharm Pharm Sci 2012;4:16–23.

74. Ayyanan M, Subhash-babu P, Syzygium cumini (L.) Skeels: a review of its phytochemical constituents and traditional uses. Asian Pac J Trop Biomed 2012;2:240–6.

75. Deb A, Barua S, Das B. Pharmacological activities of Baheda (Terminalia bellirica): a review. J Pharmaco Phytochem 2016;5:194–7.

76. Gupta PC. Biological and pharmacological properties of Terminalia chebula Retz. (Haritaki)—An overview. Int J Pharm Sci 2012;4:62–8.

77. Gnanaraj C, Haque ATME, Iqbal M. The chemopreventive effects of Thysanoaula latifolia against carbon tetrachloride
85. Wangchuk P, Keller PA, Pyne SG, Taweechotipatr M, Tonsomboon A, Rattanajak R, et al. Evaluation of an ethnopharmacologically selected Bhutanese medicinal plants for their major classes of phytochemicals and biological activities. *J Ethnopharmacol* 2011;137:730–42.

86. Wangchuk P, Navarro S, Shepherd C, Keller PA, Pyne SG, Loukas A. Diterpenoid alkaloids of Aconitum laciniatum and mitigation of inflammation by 14-O-acetylneoline in a murine model of ulcerative colitis. *Sci Rep* 2015;5:12845.

87. Wangchuk P, Pearson MS, Giacomin PR, Becker L, Sotillo J, Pickering D, et al. Compounds derived from the Bhutanese Daisy, *Ajania nubigena*, demonstrate dual anthelmintic activity against *Schistosoma mansoni* and *Trichuris muris*. *PLoS Negl Trop Dis* 2016;10:e0004908.

88. Wangchuk P, Giacomin PR, Pearson MS, Michael J, Smout MJ, Loukas A. Identification of lead chemotherapeutic agents from medicinal plants against blood flukes and whipworms. *Sci Rep* 2016;6:32101.

89. Wangchuk P, Sastraruji T, Taweechotipatr M, Keller PA, Pyne SG, Taweechotipatr M, et al. Anti-inflammatory, anti-bacterial and anti-acetylcholinesterase activities of two isoquinoline alkaloids–Scoulerine and Cheilanthifoline. *Nat Prod Commun* 2016;11:1801–4.