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

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ABSTRACT

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.

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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.[1,2] Asian medicines comprise oral-based folklore medicines (local healing system) and the scholarly TM systems. While most of the folklore 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.[4] 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 heath 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, Buddhashi, 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 Toenkhar. Similarly, Sonamthang village is made of four villages including Sonamthang, Tungudemba, Marangdud, and Panbang town area. Buddhashi includes five villages: proper Buddhashi, 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 formularies 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.[6–8] 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

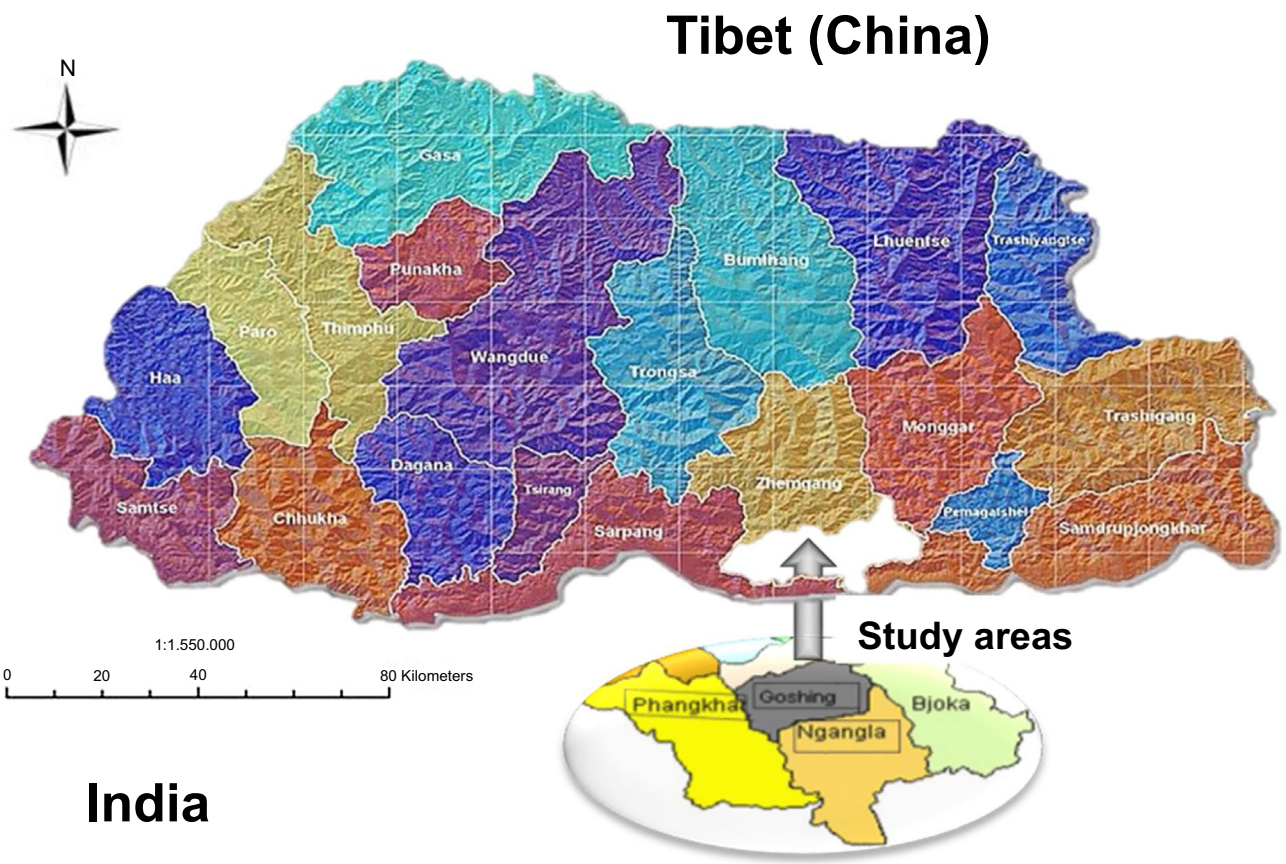

Fig. 1 – Map of Bhutan showing our study areas (Lower Kheng region, shaded white). The extended map with arrow shows the demarcation of three Gewogs: Phangkhar, Goshing, and Ngangla.

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[9–17] and other Himalayan plant publications.[18,19] The botanical names were also confirmed through *The Plant List*,[20] *eFloras*,[21] and *TROPICOS*.[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[9–22]	*Sowa Rigpa* name	Local name (Khengkha)	Life form	Status	Part used	*Sowa Rigpa* uses[6–8]	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,[23] and anti-inflammatory[24]
Aquillaria malaccensis (Thymelaeaceae)	*a-ga-ru*	*Aga-ru*	Tree	Ab	Heart wood	Useful for nervous system disorders, nervine, sedative, and refrigerant for heart disorder	Antimicrobial, anesthetic, analgesic, and positive effect on central nervous system[25–27]
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)[28]
Asparagus racemosus (Asparagaceae)	*nyi-shing*	*Nala-khag-chung*	Woody vine	Av	Root	Antiaging, defective air related disorders, pathogenic serum, anti-inflammatory	Antioxidant, antiulcer, antibacterial[29,30]
Beaumontia grandiflora (Apocynaceae)	*dug-mo-nyung*	*Ne-wai-num-phang*	Woody vine	Ab	Seed	Antitoxin, anthelmintic and vermifuge, defective bile related disorders, poisoning, and diarrhea	Antioxidant[31]
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[32–34]
Brassica juncea (Brassicaceae)	*yung-d.kar*	*Yung-kar*	Herb	Ab	Seed	Aphrodisiac, antitoxin, antiseptic, defective serum related diseases, and evil spirit afflictions	Antioxidant[35]
Brassica rapa (Brassicaceae)	*nung-ma*	*Ya-wa*	Herb	Av	Root	Antidote and vitality regeneration	Antioxidant, antimicrobial, and antidiabetic activities[36]
Buddleja bhutanica (Scrophulariaceae)	*chang-rtsi*	*Phab-seng*	Shrub	Ab	Leaf	Dyspepsia, nervine, 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[37]
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[38] and antimicrobial[39]
Capsicum annuum (Solanaceae)	*tsi-tra-ka*	*Bang-ga-la*	Herb	Ab	Fruit	Antibacterial and leprosy, digestive, and piles	Antibacterial[40], antioxidant, anti-inflammatory[41]

Table 1 (*Continued*)

Botanical name and Family[9–22]	*Sowa Rigpa* name	Local name (Khengkha)	Life form	Status	Part used	*Sowa Rigpa* uses[6–8]	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, antiulcer, and hepatoprotective[42]
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[43]
Choerospondias axillaris (Anacardiaceae)	*sning-zho-sha*	*Kru-ta-lee*	Tree	Av	Fruit	Febrifuge, cardiac tonic, drowsiness, tongue infection, chest pain, appetizer, dehydration, and calming	Antioxidant and anti-angiogenic[44]
Cinnamomum granduliferum (Lauraceae)	*a-gar-go-snod*	*Unknown*	Tree	Av	Wood	Febrifuge, cephalagic, headache, yawning, nausea, dizziness, and shivering	Antimicrobial and anticancer[45]
Cinnamomum impressinervium (Lauraceae)	*shing-tsa*	*Chin-chang*	Tree	Av	Bark	Diarrhea, carminative, flatulence, and lung infection (*glo-rnag*)	Antidiabetic [46]
Coriandrum sativum (Apiaceae)	*hu-su*	*Hon-su*	Herb	Ab	Seed	Lithontriptic and defective phlegm disorders	Atimicrobial, antioxidant, anxiolytic, analgesic, anti-inflammatory, hypoglycemic, hypolipidemic, and antitumor activities[47]
Curcuma longa (Zingiberaceae)	*yung-ba*	*Yong-ket*	Herb	Ab	Rhizome	Tonic, inflammation, sepsis, and preservative	Anti-inflammatory, antioxidant, antimicrobial, and nematocidal activities[48]
Drynaria propinqua (Polypodiaceae)	*re-rel*	*Kha-ri-shog-pa*	Epiphytic	Av	Stem	Antidote, detoxifier, and poisoning (*sbyar-dug*)	Antioxidant[49]
Entada rheedii (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[50]
Erythrina arborescens (Fabaceae)	*m.khal-ma-zho-sha-nag-po*	*Domg-leng-ma-seng*	Tree	Ab	Seed	Febrifuge for kidney disorders, urine infection, back pain, giddiness, and disabilities	Hypotensive, cytotoxic Antispasmodic, and uterine stimulant[51]
Fraxinus paxiana (Oleaceae)	*stabs-seng*	*Sib-shing*	Tree	Av	Bark	Bone fracture and infection, eye disorders, and vulnerary	Not tested
Gossypium hirsutum (Malvaceae)	*re-'bras*	*Kam-phai*	Shrub	Av	Seed	Antiepistaxis and nose disorders	Not tested

Jatropha curcas (Euphorbiaceae)	*dan-rog*	*Ching-da-lee*	Shrub	Ab	Seed	Purgative, laxative, and undoing constipation	Anti-inflammatory, analgesic, and antimicrobial activity[52]
Juglans regia (Juglandaceae)	*star-ga*	*Khu-chi*	Tree	R	Nut	Defective air related disorders (*rlung-nad*) and stiffness of limbs	Keratolytic, antifungal, hypoglycaemic, hypotensive, and sedative activities[53]
Justicia adhatoda (Acanthaceae)	*khrog-ba-sha-ka-d.kar-po*	*Khad-ka-ley*	Shrub	Ab	Leaf	Febrifuge, blood disorders, blood pressure (*khrag-g.zir*), anodyne, liver, and bile infections	Antitissive, hepatoprotective cardioprotective, anti-inflammatory, antimicrobial and muscle relaxant[54]
Knema tenuinervia (Myristicaceae)	*du-ru-ka*	*Dur-ka*	Tree	Ab	Heart Wood	Heart disorders, fever, drowsiness, tongue disorder, chest pain, appetizer, calming, and defective air-related disorders (*rlung-nad*)	Not tested
Lagenaria siceraria (Cucurbitaceae)	*ka-bed*	*Chaang*	Climber	Ab	Seed	Diarrhea and dysentery	Antimicrobial and analgesic activities[55]
Luffa aegyptiaca (Cucurbitaceae)	*g.ser-gyi-phud-bu*	*Poi-ray-la*	Climber	Ab	Seed	Emetic, detoxifier, and jaundice	Antioxidant, antimicrobial, anticancer, and anti-inflammatory[56]
Mangifera indica (Anacardiaceae)	*am-'bras*	*Am-chuku-lee*	Tree	Av	Seed	Kidney disorders, and rejuvenator	Kidney protective, immunoregulatory or rejuvenator[57]
Millettia pachycarpa (Fabaceae)	*a-'bras*	*Sadala-ruu*	Woody vine	Av	Seed	Kidney disorders	Antioxidant, estrogenic and antitumor activities[58]
Morus macroura (Moraceae)	*seng-ldeng*	*Seng-leng*	Tree	Ab	Wood	Blood purifier, defective blood and serum, wounds, and abscess	Antioxidant and antimicrobial[59]
Mucuna imbricata (Fabaceae)	*gla-gor-zho-sha*	*Ko-sha-ley*	Climber	Av	Seed	Febrifuge, spleen disorders, mouth and tongue related diseases, knee swelling, backache, numbness, and tingling sensation	Not tested
Oroxylum indicum (Bignoniaceae)	*tsam-pa-ka-me-tog*	*Nam-ka-leng*	Tree	Ab	Seed	Febrifuge and antimalarial	Antioxidant, anthelmintic, and anti-inflammatory[60]
Oryza sativa (Poaceae)	*'bras*	*Mrat*	Grass	Ab	Seed	Diarrhea, anti-emetic, demulcent, adaptogen, relaxant, aphrodisiac, restores youthfulness, and disorders originating from air, bile and phlegm	Antioxidant[61]

Table 1 (*Continued*)

Botanical name and Family[9–22]	*Sowa Rigpa* name	Local name (Khengkha)	Life form	Status	Part used	*Sowa Rigpa* uses[6–8]	Ethnopharmacologically relevant biological activities
Otochilus lancilabius (Orchidaceae)	*pu-shel-rtse*	*Agar-mentog*	Epiphytic	Av	Stem	Antiemetic, febrifuge for stomach inflammation (*bad-tshad*), and allays hyperdipsia and dehydration.	Not tested
Phlogacanthus thyrsiformis (Acanthaceae)	*khrog-ba-sha-ka-d.mar-po*	*Plum-seng-ma*	Shrub	Av	Leaf	Febrifuge, blood infection (*khrag-tshad*), painful blood pressure (*khrag-g.zir*), liver inflammation (*m.chin-tshad*), and bile disorders (*m.khris-tshad*)	Analgesic, anti-inflammatory, and antioxidant activities[62]
Phyllanthus emblica (Phyllanthaceae)	*skyu-ru*	*Plut-ching-ka*	Shrub	Ab	Fruit	Febrifuge, defective phlegm, and bile (*bad-m.khris*) disorders	Antimicrobial, anti-oxidant, anti-inflammatory, hepatoprotective, antitissuive, immunomodulatory, hypolipedemic, anticancer, antidiabetic, and wound healing activities[63]
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	Antiplatelet aggregation and insecticidal[64]
Quercus griffithii (Fagaceae)	*mon-cha-ra*	*Pe-seng*	Tree	Ab	Nut	Diarrhea	Not tested
Raphanus sativus (Brassicaceae)	*la-phug*	*Ya-wa*	Herb	Ab	Root	Gastrointestinal, throat and lung infections, and antiasthma	Gastrointestinal stimulation and gut protective effects, antioxidant, antibacterial, hepatoprotective, immuno-modulatory, and cholesterol lowering[65]
Rhus chinensis (Anacardiaceae)	*da-trig*	*Blam-dung*	Tree	Ab	Fruit	Purgative, emetic, appetizer, asthma, and lung rejuvenator	Antioxidant, anticancer, antiviral, antimicrobial, antidiarrheal, anti-inflammatory, and antithrombin activities[66]
Ricinus communis (Euphorbiaceae)	*dan-khra*	*Cha-me-la*	Shrub	Ab	Seed	Purgative, emetic, indigestion, and gastrointestinal disorders	Antioxidant, anti-inflammatory, and hepatoprotective[67]
Rubia manjith (Rubiaceae)	*b.tsod*	*Tshud*	Climber	Av	Stem	Hematinic, blood disorders, and debilitating chronic fever	Coagulation-fibrinolytic system regulator, antiplatelet, antidiabetic, hepatoprotective[68]

Rubus ellipticus (Rosaceae)	*ga-bra*	*Meleep*	Shrub	Av	Bark	Cough and cold and blood disorders (*rlung-khrag*)	Antioxidant and antiproliferative[69]
Saccharum officinarum (Poaceae)	*bur-shing*	*Chaag*	Grass	Ab	Stem	Analgesic, hyperdipsia and dehydration, nausea, vertigo, fainting, and bile disorder	Analgesic, antihepatotoxic, antihyperglycemic, antithrombotic, anti-inflammatory, antihypercholesterolemic[70]
Sapindus rarak (Sapindaceae)	*po-so-cha*	*Na-ka-pa-nee*	Tree	Av	Fruit	Emetic; local people use it as shampoos for head lice	Not tested
Selaginella involvens (Selaginellaceae)	*sngo-chu-srin-sder-mo*	*Unknown*	Grass	R	Leaf	Dropsy, bone fracture and stiffness of limbs	Antibiotic and antimicrobial[71]
Sesamum indicum (Pedaliaceae)	*til-d.kar*	*Pleem*	Herb	Ab	Seed	Nourishes and replenishes body, defective air related disorders, and improves sperm and ova production	Antioxidant andantiatherogenic[72]
Stephania glabra (Menispermaceae)	*d.po'-ser-po*	*Ru-ku-du-mang*	Climber	R	Tuber	Febrifuge for poisoning (*dug-tshad*)	Analgesic, antipyretic, antimicrobial, antihyperglycemic, and anthelmintic[73]
Symplocos sumuntia (Symplocaceae)	*zhu-m.khan*	*Zhem*	Shrub	R	Leaf	Febrifuge for chronic lung infection and kidney diseases (*'gram-tshad*)	Not tested
Syzygium cumini (Myrtaceae)	*sra-'bras*	Unknown	Tree	Av	Fruit	Replenishes kidney and heals kidney disorders	Antidiabetic, antioxidant, anti-inflammatory, and gastroprotective[74]
Terminalia bellirica (Combretaceae)	*ba-ru*	*Ba-ru-la*	Tree	Av	Fruit	Cholagogue, hydragogue, gout, arthritis, leprosy (*chu-ser-nag-po*), defective bile (*bad-m.khris*) disorders, and for hair loss	Analgesic, antimicrobial, anti-oxidant, immune-regulatory, anticancer, hepatoprotective[75]
Terminalia chebula (Combretaceae)	*a-ru*	*Aru-la*	Tree	Av	Fruit	Restore three defective humors and bodily constituents, anti-dysenteric, anti-diarrheal, chronic lung and kidney infections, and cough and cold	Cytoprotective, anti-aging, hepatoprotective, anti-oxidant, antimutagenic, anticancer, antimicrobial, anthelmintic, antiplasmodial, anti-arthritic, antidiabetic, antinociceptive, antianaphylactic and adaptogenic activities[76]

Table 1 (*Continued*)

Botanical name and Family[9–22]	*Sowa Rigpa* name	Local name (Khengkha)	Life form	Status	Part used	*Sowa Rigpa* uses[6–8]	Ethnopharmacologically relevant biological activities
Thysanolaena latifolia (Poaceae)	*rtsa-ku-sha*	*Phig-shang*	Grass	Ab	Flower	Antiaging; nourishes body and increases longevity	Chemopreventative, antioxidant and hepatiprotective[77]
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 chemopreventative[78]
Triticum aestivum (Poaceae)	*dro*	*Kar*	Grass	Av	Seed	Aphrodisiac, nourishes body and defective air and bile (*rlung-m.khris*) related disorders	Antioxidant, antiarthritic, antiulcer, and anticancer activities[79]
Xanthium indicum (Asteraceae)	*byi-tsher*	*Ra-wa*	Herb	Av	Fruit	Febrifuge, cold and flu, poisoning (*dug-tshad*), kidney disorders (*m.khel-tshad*), and air-related disorders	Antitussive, antibacterial, antifungal, antitumor, anticancer, anti-inflammatory, antiparasitic, and antioxidant[80]
Zanthoxylum armatum (Rutaceae)	*g.yer-ma*	*Cha-wa*	Shrub	Ab	Fruit	Antimicrobial, vasodilator, dermatological diseases, dispels alcohol hangover, food poisoning, indigestion, and progresses melodious voice	Antimicrobial, antiparasitic, hepatoprotective, anti-inflammatory, and keratinocyte inhibitor[81]
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[82]

Ab, abundant; Av, available; R, Rare.

Table 2 – Number of medicinal plant species in each family.

Family	No. of plant species	Family	No. of plant species
Acanthaceae	2	Moraceae	1
Anacardiaceae	3	Myristicaceae	1
Apiaceae	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	Symplocaceae	1
Malvaceae	3	Thymelaeaceae	1
Menispermaceae	2	Zingiberaceae	3

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* (churu), which are locally considered "King of Medicine" (*Mengi-Pawo*) or "Three Powerful Medicines", were all found growing in moderation or abundantly in all the three Gewogs. *Aquillaria 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.

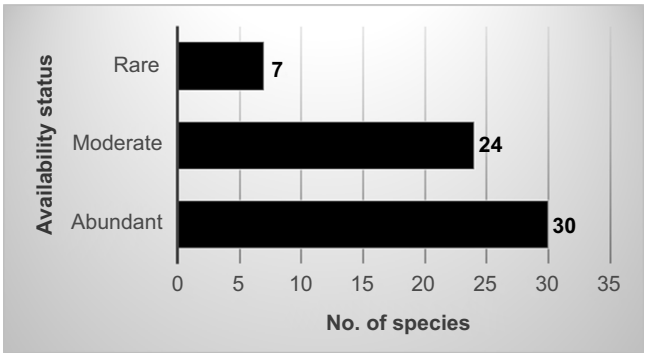

Fig. 2 – Availability status of low-altitude medicinal plants in Lower Kheng.

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 thyrsiformis* (*Krog-basha-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 Phangkhar Gewog with 31.1% and Ngangla with 28% (Fig. 5). More than 20 medicinal plants species, including *Phyllanthus emblica*, *Tinospora cordifolia*, *Cassia tora*, *Phlogacanthus thyrsiformis*, *Justicia adhatoda*, *Cautleya spicata*, *Stephania glabra*, *Canarium strictum*, *Otochilus lancitabius*, *Piper mullesua*, *Bombax ceiba*, *Erythrina arborescens*, *Knema tenuinervia*, *Rhus chinensis*, *Cinnamomum impressinervium*, *Aquillaria malaccensis*, *Symplocos sumuntia*, *Mucuna imbricata*, *Terminalia chebula*, and *Choerospondias 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 annuum*, *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

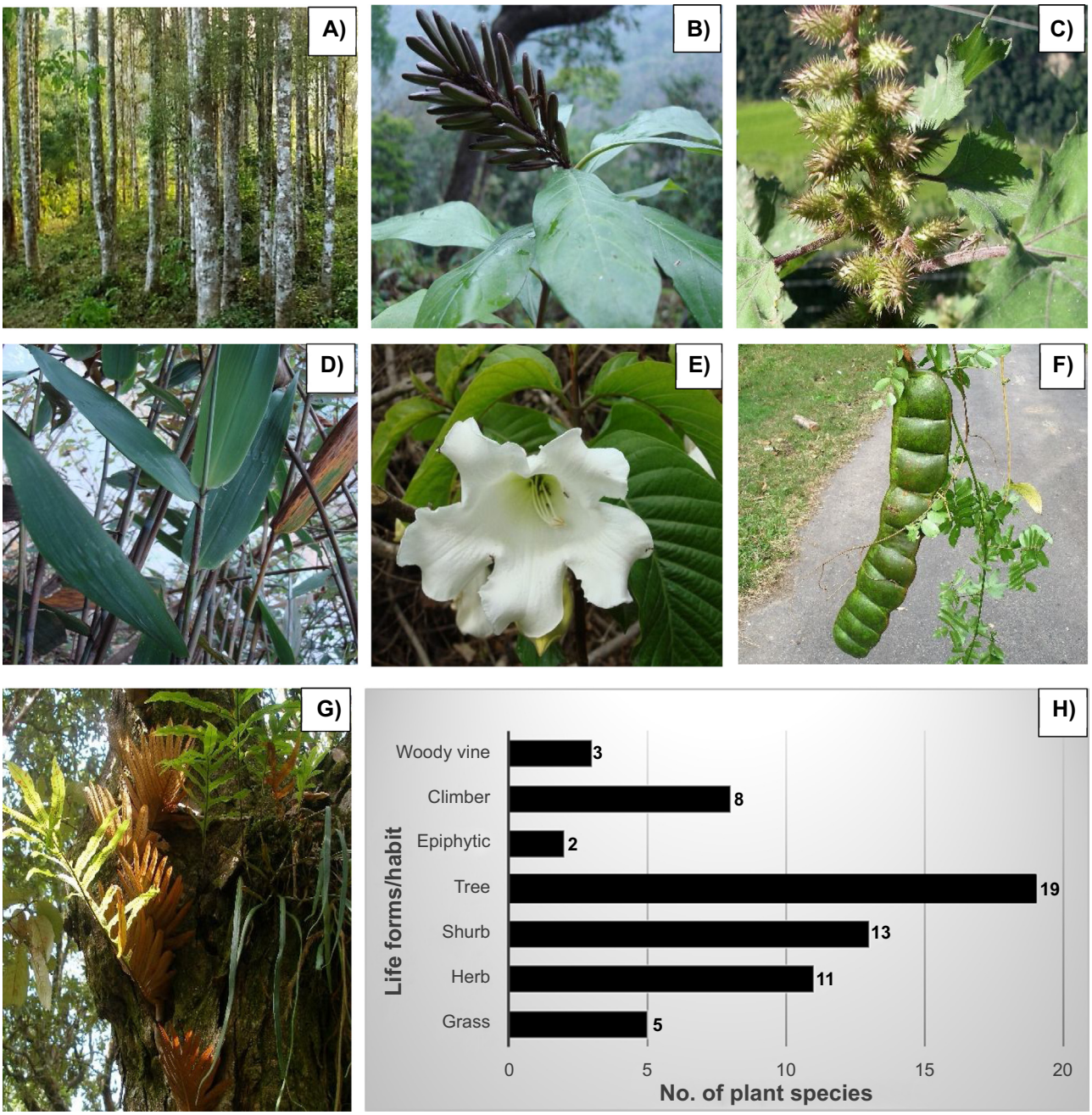

Fig. 3 – Low-altitude medicinal plants representing seven different life forms (courtesy: P.W collection). (A) *Aquillaria malaccensis* represents a tree life form. (B) *Phlogacanthus thyrsiformis* represents a shrub life form. (C) *Xanthium indicum* represents herbaceous life form. (D) *Thysanolaena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

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.

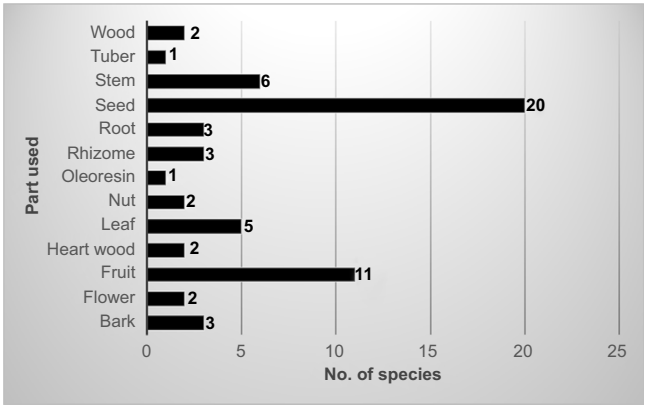

Fig. 4 – Number of low-altitude medicinal plants that can be collected for their parts.

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 Phangkhar 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.

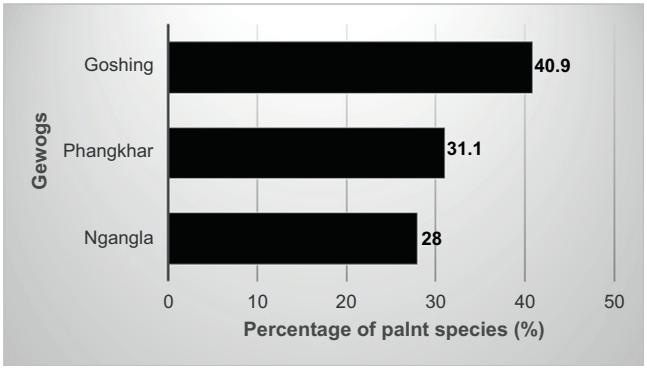

Fig. 5 – Gewog-wise distribution of medicinal plants in the Lower Kheng region.

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 thyrsiformis* (*Krog-basha-ka-marpo*; 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, *Aquillaria 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. *Aquillaria 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 *Aquillaria 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*, *Lagenaria 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.[85] 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 *Sowa 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.[1] 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[6,7]; and (6) initiate biodiscovery and value addition on the subtropical medicinal plants using the approaches described.[85–89] 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.

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