Putative Anthelmintic Plants Used in Traditional Medicine System of Kokrajhar District, India

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Research

Abstract

Background: Traditional medicine (TM) is a common practice among tribal communities of India. The present study has been designed to collect the ethnomedicinal plants used by the Bodo community of Kokrajhar district of India traditionally consumed to cure helminth infection.

Methods: A total of 54 villages were surveyed from the Kokrajhar district. Twenty adjacent villages were taken as a cluster, and one informant was interviewed face-to-face with the help of a readymade questionnaire. Traditional knowledge system of anthelmintic herbal medicines such as the name of the plants, parts used, methods of formulation, and mode of uses was collected. The demography of the informants was also collected.

Results: Total of 64 species of traditionally used anthelmintic plants belonging to 38 families were documented from Kokrajhar district, India. *Andrographis paniculata* was the most popular plant, followed by *Alstonia scholaris, Ananas comosus,* and *Azadirachta indica*. Poaceae was the most popular plant family with six species of anthelmintic plants. The leaves were the most commonly used plant-part (63%), followed by barks and tubers. Raw, decoction and infusion were the standard method of traditional formulations reported from the district. Fresh and raw plant parts in the form of paste or balls and oral consumption were the primary means of administration. Demographically, most of the knowledge bearers were found to be illiterate and aged above 50 years of age.

Conclusions: The medicinal plants reported in the present study could be a source of important medicines. A proper scientific study needs to be carried out to study the efficacy of the traditional formulations to ascertain their bioactivity.

Keywords: Ethnomedicine, Anthelmintic, Tribal Community, Kokrajhar

Background

The traditional use of plants and animals as medicines to cure diseases is an age-old practice throughout the world. Ethnomedicinal knowledge systems are transferred from one generation to the next without any formal means of communication (Samy & Ignacimuthu 2000; Verpoorte *et al.* 2005; Vitalini *et al.* 2013). Despite better healthcare facilities of the contemporary world, there is growing attention towards plant-derived compounds and their biological properties. According to the WHO Traditional Medicinal Strategy 2014-23 (WHO 2013), there is a rising

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demand for ethnomedicinal practices and practitioners worldwide. Plants are readily available, possesses fewer side effects, and are sometimes more efficacious than commercial drugs. Because of these properties, the application of plant-based products and medicines are increasing day by day (WHO 2013, Barkaoui *et al.* 2017; Aziz *et al.* 2018). Over the decades, scientific studies have explored the bioactivity of several plants, leading to the development of new therapeutic drugs. Many studies have revealed medicinal properties against various diseases, including helminthiasis (Maphosa & Masika 2010; Barkaoui *et al.* 2017; Aziz *et al.* 2018; Chaudhury *et al.* 2015; Adeniyi *et al.* 2018). In the run for new drugs discovery, the ethnomedicinal knowledge system can play a significant role. Today, the pharmacological study based on ethnomedicinal knowledge system is a major research area in the drug discovery pipeline. Ethnomedicinal studies have gained interest among the researchers to find important plant species and develop new medicines against the diseases (Pendry *et al.* 2005; Watkins *et al.* 2011). In many societies, the practice of herbal medicine systems is popular and culturally accepted by the people. For example, in India, people with different cultural backgrounds practice traditional medicines for common diseases (Gogtay *et al.* 2002). Helminthiasis is a severe tropical disease that affects millions of people and the livestock as well as the poultry industries (Kumar & Nain 2013; Das & Laha 2017; Dixit *et al.* 2017; Salam & Azam 2017). According to WHO, about 870 million children living in tropical countries worldwide are affected by helminthiasis. India alone contributes nearly 25% of it, with 220 million children that require medical attention (Lobo *et al.* 2011). Despite improved health facilities, sanitation, drinking water, and mass deworming programs, helminthiasis remain a grave health issue in several states of India (Salam & Azad 2017). In addition to poor economic conditions, most rural Indians cannot access commercial anthelmintic drugs because of geographical isolation and the high cost of the drugs. However, as an alternative, locally available traditional medicines become the first choice for healthcare needs (Tandon *et al.* 2011).

The northeastern region (NER) of India, consisting of eight member states, including Assam, covers an area of 262,230 km^2. NER is one of the 35th biodiversity hotspots on earth with rich flora and fauna (Mittermeier *et al.* 2011). As per the 2011 census of India, NER has over 220 ethnic groups speaking more than 220 different languages. In Assam, tribal communities are concentrated mainly in the Bodoland Territorial Region (BTR), formed by curving eight districts of Assam (BTC 2003). There are four districts under Bodoland Region, namely Kokrajhar, Chirang, Baksa, and Udalguri, administered by the Bodoland Territorial Council (BTC). *Bodo*, *Rabha*, and *Rajbonghis* represent the major tribal communities of the Bodoland area. The practice of the traditional medicine systems is widespread and prominent among the tribal communities of BTR. However, the practice of ethnomedicine differs from community to community. Different communities have different ways and means of practising and preserving their ethnomedicinal knowledge systems (Kotoky & Das 2008; Shankar *et al.* 2012). It varies from common household remedies to the treatment of severe diseases with specialised treatment processes. People that are involved in traditional healing are locally known as '*kaviraja*' or '*ojhas*'. Several studies have investigated and documented the ethnobotanical aspects of herbal medicines against several diseases in Assam (Purkayastha *et al.* 2005; Das *et al.* 2006; Narzary *et al.* 2013; Swargiary *et al.* 2013, 2016; Tamuli & Ghosal 2017; Sonowal & Barua 2017). Like many other parts of Assam, the Bodoland area is full of natural flora and fauna. Despite abundant medicinal plants, no scientific study has been conducted to explore the ethnobotanical knowledge of this part of India. Therefore, the present study is designed to explore the diversity of medicinal plants used to cure helminth infection (locally known as '*kirmi*') by the Bodo community of Kokrajhar district of India.

Methods and Materials

Study area and its description

The survey was carried out in the Kokrajhar district of Assam (India), which covers 3,169.22 sq. km (longitude 89°46′ East to 90°38′ East and latitude 26°19′ North to 26°54′ North). Located on the northern side of the River Brahmaputra, the district is plain land with small hillocks bounded by the Himalayan Foothills of Bhutan on the northside, Chirang district on the east, West Bengal on the west, and Dhubri district on the southside. With lush green forest, and rich flora and fauna, the climatic conditions of the district are sub-tropical with warm and humid summer (27.64°C to 31.67°C) followed by cool and dry winter (19.34°C to 23.66°C) with an annual average rainfall of 2,400 mm to 3,000 mm. Out of 887,142 populations inhabiting 1053 villages, nearly 94% live in rural areas, while 31% belong to scheduled tribe communities. According to the 2011 census, Kokrajhar has a literacy rate of 65.2% (Census of India, 2011). For administrative purposes, the Kokrajhar district has been divided into small Community Developmental Blocks (CDB). The entire district consists of 11 CDBs, namely, (1) Kokrajhar (Titaguri), (2) Dotoma, (3) Kochugaon, (4) Gossaigaon, (5) Hatidhura, (6) Bilasipara (Part), (7) Chapar-Salkocha (Part), (8) Rupshi (Part), (9) Mahamaya (Part), (10) Golokganj (Part), and (11) Debitola (Part). Out of the 11 CDBs, Kochugaon is having the highest number of villages (238 nos.) followed by Kokrajhar (224 nos.), Dotoma (172 nos.), Debitola (138 nos.), Gossaigaon (112 nos.), Hatidhura (44 nos.), Rupsi (43 nos.), Chapar-Salkocha (36 nos.), Mahamaya (34 nos.), Golokganj (8 nos.) and Bilasipara with four numbers of villages. Kokrajhar is the biggest CDB, followed by Kochugaon, Debitola, Dotoma, Gossaigaon, Rupsi, Chapar-Salkocha, Hatidhura, Mahamaya, Bilasipara, and Golokganj.

Data collection and identification of plants

The survey and collection of anthelmintic medicinal plants were carried out from April to October 2018. The information regarding the medicinal plants was collected in a CDB-wise manner with the help of local traditional healers. The ethnomedicinal data was also collected from older people having traditional medicine knowledge. Both males and females were involved in the survey work. Within every CDB, approximately 20 nearby villages were taken as a single cluster, and one sample was collected. The information was collected by face-to-face interview manner with the help of a readymade questionnaire. Based on the number of villages of CDBs, the sample size also varied from one CDB to another. The information collected from informants mainly included the informer's bio-data, plant(s) part(s) used, traditional formulation processes and mode of administration. Total, 54 informants were interviewed from 54 different villages under the district, and traditional knowledge about anthelmintic plants was collected. Sample plants were collected, herbarium sheets were prepared and submitted to the Department of Botany, Bodoland University, to identify the plant samples.

Data analysis

All the statistical calculations, graphs were carried out in Microsoft Excel and OriginPro-8.5 software. The data were analysed by comparing several parameters such as the number of plant species, families, plant parts used, modes of utilisation, habit, and habitat.

The quantitative analysis was carried out to evaluate the importance of plants following Hussain *et al.* (2018).

Frequency of Citation (FC) is the number of informants who mentioned a certain species.

Relative frequency of citation (RFC): It is obtained by dividing FC by total number of informants (N). The value of RFC indicates the citing percentage of each species of plant. RFC is calculated by using the following formula (Tardio *et al.* 2008):

$$RFC = FC / N$$

The value of RFC varies from zero (when nobody cites to a plant as important) to one (when all the informants consider a certain species important).

Family importance value (FIV): FIV indicates the local importance of the families of plant species and is calculated by counting the percentage of informants mentioning a specific family (Vitalini *et al.* 2013).

$$FIV = [FC (Family) / N] \times 100$$

Results

The present study surveyed 54 villages from 11 CDBs of Kokrajhar district to collect anthelmintic medicinal plants. Traditional healers and older knowledgeable persons were involved in the data collection. The name of CDBs, name of the villages and their geographical locations are shown in Table 1. A highest of 12 villages were surveyed from Kochugaon CDB, followed by Kokrajhar, Dotoma, Debitola, Gossaigaon, Rupsi, Chapar-Salkocha, Hatidhura, and Mahamaya development blocks. No data was collected from Golokganj (Part) and Bilasipara (part) because of fewer villages and the absence of tribal communities in the particular blocks (Table 2). Figure 1 indicates the information collection sites. Out of the total 54 informants, 37 were males, and 17 were females. Most of the knowledge bearers were aged people. About 74% of the total informants were >50 years old, followed by 26% in 40 - 50 years old. In terms of literacy, most of the informants (48%) had school-level education, 19% have college-level education, and 33% do not have any formal education. Among the 54 informants, very few (7%) have salaried government jobs. Most of the informants from Kokrajhar and Kochugaon CDBs were literate, while informants from other CDBs were illiterate. The study also observed that both the literate and illiterates possess almost equal knowledge in terms of plant citation. On average, one literate informant named 4.6 plant citations, while illiterate named 5.0 plant citations. About 72% of the total informants were professional healers who practice traditional healing on a daily basis and earn little money. In comparison, 28% of older knowledgeable people do not get involved in traditional healing practices.

Table 1. Demographic characteristics of informants of Kokrajhar district, India.

	Literacy			Age group		Informants		
Block	**School**	**College**	**Illiterate**	**>50**	**40-50**	**Kaviraja**	**Older**	**Total**
Kokrajhar	3	6	2	9	2	8	3	11
Kochugaon	7	2	3	9	3	10	2	12
Dotoma	3	2	4	6	3	4	5	9
Debitola	4	0	4	4	4	7	1	8
Gossaigaon	4	0	3	5	2	5	2	7
Rupsi	2	0	1	3	0	2	1	3
Chapar-Salkocha	2	0	0	2	0	1	1	2
Hatidhura	0	0	1	1	0	1	0	1
Mahamaya	1	0	0	1	0	1	0	1
Total	**26**	**10**	**18**	**40**	**14**	**39**	**15**	**54**

Table 2. List of villages where information regarding traditionally used anthelmintic medicinal plants was collected along with the geographical location.

CD Block	List of villages	Geographical location
Kokrajhar	Athiabari	26°58′48.66″N 90°20′38.75″E
	Bashbari	26°35′09.16″N 90°12′13.84″E
	Batipara	26°22′40.17″N 90°15′23.14″E
	Bhowraguri	26°36′09.86″N 90°14′24.07″E
	Chilaguri	26°28′35.26″N 90°12′04.06″E
	Latagaon	26°29′03.41″N 90°20′36.29″E
	Mawriagaon-II	26°27′04.83″N 90°08′40.14″E
	Pakriguri	26°31′00.58″N 90°14′32.44″E
	Ranighuli	26°19′53.71″N 90°16′11.16″E
	Shamthaibari	26°22′40.96″N 90°18′22.35″E
	Sutarpara	26°29′36.69″N 90°20′38.95″E
Chapar-Salkocha (Pt.)	Bamungaon Pt.IV	26°29′05.81″N 90°28′05.83″E
	Chakrasila Pt.I	26°28′88.38″N 90°36′76.96″E
Dotoma	Baghmar	26°28′38.78″N 90°08′48.01″E
	Bauti	26°29′29.72″N 90°09′19.26″E
	Bhalukmari	26°29′56.05″N 90°12′12.12″E
	Boragari	26°27′07.21″N 90°08′36.27″E
	Dangarkhuti	26°27′21.23″N 90°12′21.58″E
	Dotoma Bazar	26°28′06.87″N 90°09′02.61″E
	Ghoramar	26°32′54.97″N 90°48′20.83″E
	Narenguri	26°29′19.30″N 90°05′23.74″E
	Dumuriguri	26°26′11.96″N 90°04′59.02″E
Gossaigaon	Balapara-Siljhar	26°32′24.60″N 90°10′40.43″E
	Banglabari	26°39′90.55″N 90°03′27.32″E
	Bhowraguri	26°36′06.15″N 90°14′24.83″E
	Gossaigaon-I	26°42′84.87″N 89°99′88.33″E
	Madati	26°41′84.03″N 90°02′27.54″E
	Mowamari	26°42′46.90″N 90°10′77.73″E
	Singimari-II	26°36′04.09″N 89°99′01.02″E
Kochugaon	Balagong	26°58′17.06″N 90°07′53.78″E
	Chengmari FV	26°32′55.30″N 89°56′37.73″E
	Gombariguri	26°51′13.51″N 90°11′98.16″E
	Haldibari FV	26°36′08.48″N 89°54′08.78″E
	Jonaligaon FV	26°64′69.75″N 89°94′36.99″E
	Karikar FV	26°32′49.27″N 90°05′12.04″E
	Kumguri FV	26°53′98.81″N 90°15′97.63″E
	Kumtola FV	26°32′52.96″N 90°03′23.55″E
	Lotamari FV-II	26°56′89.20″N 90°10′86.83″E
	Salbari FV	26°56′50.57″N 90°00′08.17″E
	Takampur FV	26°60′29.82″N 90°03′51.70″E
	Kathalguri	26°52′17.60″N 90°00,58.82″E
Debitola (Pt.)	Borshijhora Pt-II	26°21′65.21″N 89°96′23.53″E

	Daibari Pt.-I	26°26′92.97″N 89°97′80.08″E
	Daimaguri-I	26°30′46.58″N 90°05′36.79″E
	Dampur –II	26°12′20.56″N 90°02′53.42″E
	Debitola Pt.-II	26°15′76.43″N 90°00′75.26″E
	Dholagaon Pt.-I	26°20′61.94″N 90°02′04.14″E
	Duligaon Pt.-III	26°25′98.01″N 90°07′24.97″E
	Kazigaon Pt.-I	26°19′21.79″N 89°99′46.81″E
Mahamaya (Pt.)	Silbari	26°13′52.68″N 89°97′82.28″E
Rupsi (Pt.)	Basbari	26°18′93.98″N 89°90′26.52″E
	Dukhisukhijhar Pt.-I	26°16′60.90″N 89°89′27.91″E
	Malatijhora	26°16′97.28″N 89°95′99.30″E
Hatidhura (Pt.)	Hatidhura	26°29′14.89″N 90°15′41.86″E

*Part (Pt.) means some villages of Debitola, Mahamaya, Rupsi, Chapar-Salkocha, and Hatidhura block comes under the Dhubri district. Some under Kokrajhar district, and the villages that come under Kokrajhar district is written as 'Part'. FV - forest village.

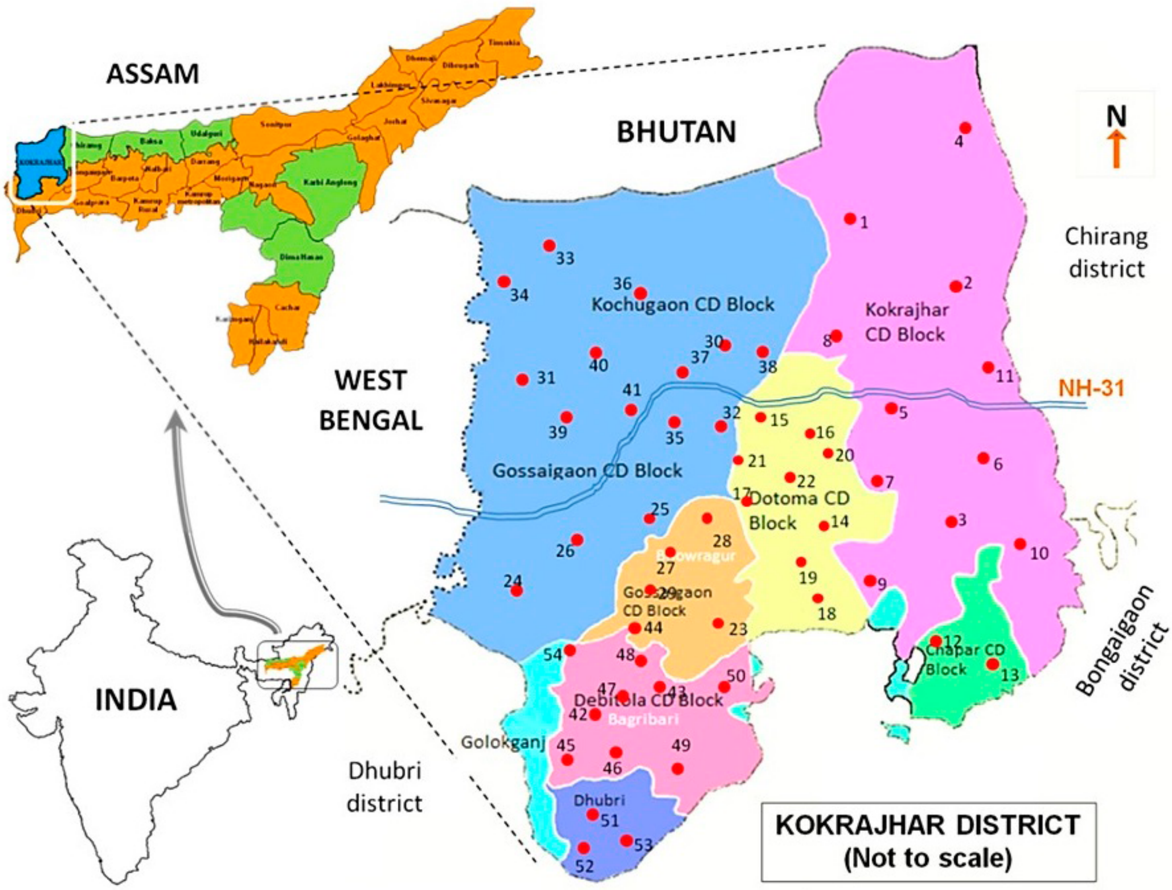

Figure 1. Map of Kokrajhar district and community development blocks indicating the information collection sites. Data collection sites were shown in red spots. The number represents the serial number of Table 1. NH-31- National Highway no. 31.

The name of the plant species (sp.), local name (in Bodo), habit, habitat, parts used, and the traditional formulations is shown in Table 3. A total of 169 plant citations were reported from the survey data. Total of 64 species belonging to 38 families used in the traditional formulations of anthelmintic medicine were documented from the study area. Out of total citations, 23 sp. were repeated more than once by the informants consisting of about 75% (127 citations) of the total citations, while 25% (42 citations) do not have any repetitions. The FC and and RFC values are presented in Table 3. Plants belonging to 15 families were found more popular with more than one species citation. Six plants were reported from the Poaceae, followed by four sp. from Arecaceae, three sp. from Apocynaceae, Asteraceae, Euphorbiaceae, Fabaceae, Lamiaceae, Rutaceae, and Zingiberaceae. Two plant species were reported from Acanthaceae, Polygonaceae, Rubiaceae, Solanaceae, and Verbenaceae. The percent relative importance of family is shown in Figure 2.

Table 3 List of plant species, parts used and mode of traditional formulation, and identification number used in the traditional medicine system of tribal communities of Kokrajhar district to control helminth infection.

Species name & herbarium number	**Family**	**Habit**	**Habitat**	**Local name (Bodo)**	**Parts used**	**TF**	**FC**	**RFC**	**References**
Andrographis paniculata (Burm.f.) Nees [BUBH0000009]	Acanthaceae	Herb	D	kalmech, sirota tita	L	Raw	26	0.481	Yes, (Singh *et al.* 2009; Kamaraj *et al.* 2011)
Phlogacanthus tubiflorus Nees. [BUBH0000028]	Acanthaceae	Shrub	W	basikhor	L	Raw	1	0.018	No
Achyranthes aspera L. [BUBH0000046]	Amaranthaceae	Herb	W	ulta sur, somper ulta	L, Fr	Raw/ mixture	1	0.018	Yes, (Ndhlala *et al.* 2015)
Alstonia scholaris (L.) R. Br. [BUBH0000040]	Apocynaceae	Tree	W	sithona	B	Infusion	14	0.259	No
Holarrhena antidysenterica (L.) Wall. [BUBH0000033]	Apocynaceae	Tree	W	dukhuri	B	Infusion	1	0.018	No
Rauvolfia tetraphylla L. [BUBH0000013]	Apocynaceae	Shrub	W	kharwkha	R, B, L	Raw/ mixture	7	0.129	No
Typhonium trilobatum (L.) Schott [BUBH0000061]	Araceae	Herb	D	sanka dongfang	T	Raw/ mixture	1	0.018	No
Hydrocotyle asiatica L. [BUBH0000020]	Araliaceae	Herb	W	manimuni gidir	L, WP	Raw/ mixture	4	0.074	No
Hydrocotyle sibthorpioides Lam. [BUBH0000019]	Araliaceae	Herb	W	manimuni fisa	L, WP.	Raw/ mixture	4	0.074	No
Calamus tenuis Roxb. [BUBH0000059]	Arecaceae	Scandent Shrub	D	riding bendwng	L	Decoction	1	0.018	Yes, (Das *et al.* 2017)
Phoenix dactylifera L. [BUBH0000017]	Arecaceae	Shrub	D	kijuri	L	Raw/ mixture	1	0.018	No
Asparagus racemosus Willd. [BUBH0000063]	Asparagaceae	Climber	W	nilikhor	R	Raw/ mixture	6	0.111	Yes, (Gupta *et al.* 2012)
Acmella paniculata (Wall. ex DC.) R.K.Jansen [BUBH0000007]	Asteraceae	Herb	W	jhari, usumwi	L	Raw/ mixture	2	0.037	Yes, (Rajeshwar & Lalitha 2013)
Chromolaena odorata (L.) R.M.King & H.Rob. [BUBH0000005]	Asteraceae	Shrub	W	jharman, bangri lewa	L	Infusion	1	0.018	Yes, (Sheela & Viswanathan 2009; Mishra *et al.* 2010)
Mikania micrantha Kunth. [BUBH0000058]	Asteraceae	Climber	W	refugee bendwng	L	Raw/ mixture	3	0.055	No
Oroxylum indicum (L.) Kurz [BUBH0000012]	Bignoniaceae	Tree	W	kharao khandai	B, Fl	Decoction	1	0.018	Yes, (Deori & Yadav 2016), no literature for leaves & flowers.
Cordia dichotoma G. Forster. [BUBH0000065]	Boraginaceae	Tree	W	doba kharwi	B	Infusion	1	0.018	No

Ananas comosus (L.) Merr. [BUBH0000025]	Bromeliaceae	Herb	D	anaros	Lt	Infusion/ mixture	12	0.222	Yes, (Hordegen *et al.* 2006; Domingues *et al.* 2013; Ahmed *et al.* 2014)
Terminalia chebula Retz. [BUBH0000062]	Combretaceae	Tree	D	silikha	Fr	Raw/ mixture	1	0.018	Yes, (Dwivedi *et al.* 2008; Behera & Bhatnagar 2018)
Bryophyllum pinnatum (Lam.) Oken [BUBH0000057]	Crassulaceae	Herb	D	paat gaja	L	Decoction	1	0.018	Yes, (Lunkad *et al.* 2016)
Dryopterix filix-mas (L.) Schott [BUBH0000060]	Dryopteridaceae	Herb	W	sal daokhumwi	L	Decoction	1	0.018	Yes, (Urban *et al.* 2008)
Equisetum debile Roxb. *ex* Vaucher. [BUBH0000053]	Equisetaceae	Herb	W	noljora	St	Infusion	1	0.018	No
Euphorbia neriifolia L. [BUBH0000038]	Euphorbiaceae	Shrub	D	sijou	L, Lx	Raw/ mixture	1	0.018	No
Phyllanthus emblica L. [BUBH0000023]	Euphorbiaceae	Tree	D	amla	Fr	Raw	2	0.037	No
Ricinus communis L. [BUBH0000003]	Euphorbiaceae	Shrub	D	indi	L	Infusion/ mixture	2	0.037	Yes, (Zahir *et al.* 2012; Mahadev *et al.* 2017)
Cassia fistula L. [BUBH0000043]	Fabaceae	Tree	W	sonalu	L	Infusion/ mixture	1	0.018	No
Clitoria ternatea L. [BUBH0000050]	Fabaceae	Herb	D	neel	Lt	Raw/ mixture	1	0.018	Yes, (Khadatkar *et al.* 2008; Gollen *et al.* 2018)
Sesbania grandiflora (L.) Pers. [BUBH0000004]	Fabaceae	Tree	W	jayanti	L	Raw	1	0.018	Yes, (Karumari *et al.* 2014; Meenakshisundaram *et al.* 2016)
Clerodendrum infortunatum L. [BUBH0000047]	Lamiaceae	Shrub	W	mwkhwna	L	Decoction	1	0.018	Yes, (Das *et al.* 2011; Swargiary *et al.* 2016)
Leucas aspera (Willd.) Link. [BUBH0000010]	Lamiaceae	Herb	W	kansinsa	L	Raw	2	0.037	Yes, (Agarwal *et al.* 2011)
Ocimum sanctum L. [BUBH0000045]	Lamiaceae	Shrub	D	tulungsi (fisa)	L	Raw/ Mixture	1	0.018	Yes, (Kalarickal *et al.* 2015; Kanojiya *et al.* 2015)
Peliosanthes bakeri Hook.f. [BUBH0000039]	Liliaceae	Herb	W	sikho	T	Infusion	1	0.018	No
Lindernia crustacea (L.) F.Muell. [BUBH0000048]	Linderniaceae	Herb	W	na bikhi	L	Decoction	1	0.018	No
Punica granatum L. [BUBH0000031]	Lythraceae	Shrub	D	dalim	B (root)	Raw	1	0.018	Yes, (Aggarwal & Bagai 2017; Yones *et al.* 2016)
Azadirachta indica A. Juss. [BUBH0000051]	Meliaceae	Tree	D	neem	L	Raw/ mixture/ Decoction	10	0.185	Yes, (Costa *et al.* 2006; Chagas *et al.* 2008; Iqbal *et al.* 2010)

Tinospora cordifolia (Willd.) Miers [BUBH0000024]	Menispermaceae	Climber	D	amor lata	St	Raw/ mixture	1	0.018	No
Moringa oleifera Lam. [BUBH0000042]	Moringaceae	Tree	D	sojona	L	Decoction	5	0.092	Yes, (Nilani *et al.* 2012; Cabardo & Portugaliza 2017)
Psidium guajava L. [BUBH0000041]	Myrtaceae	Tree	D	sofari, somfreng	Lt	Raw/ mixture	8	0.148	Yes, (Molla & Bandyopadhyay 2014; Pina-Vázquez *et al.* 2017)
Pandanus tectorius Parkinson ex Du Roi [BUBH0000011]	Pandanaceae	Herb	W	kewa	L	Infusion	1	0.018	No
Sesamum indicum L. [BUBH0000036]	Pedaliaceae	Herb	D	sibing	Sd	Infusion	1	0.018	Yes, (Mostafa Kamal *et al.* 2015)
Piper nigrum L. [BUBH0000035]	Piperaceae	Climber	D	golmoris	Sd	Raw/ mixture	1	0.018	No
Cynodon dactylon (L.) Pers. [BUBH0000032]	Poaceae	Herb	W	dubri hagra	R	Raw /mixture	2	0.037	Yes, (Pal & Pandab 2010; Yadav & Nath 2017)
Paspalum fimbriatum Kunth. [BUBH0000027]	Poaceae	Herb	W	dapsa	L	Raw	1	0.018	No
Saccharum ravennae (L.) L. [BUBH0000034]	Poaceae	Grass	W	engkhwr	Lt	Raw/ mixture	1	0.018	No
Saccharum sponteneum L. [BUBH0000014]	Poaceae	Herb	W	khasi dara	L	Raw/ mixture	2	0.037	No
Sacciolepis myosuroides (R.Br.) A. Camus [BUBH0000054]	Poaceae	Herb	W	nwlw dongfang	Lt	Raw	1	0.018	No
Zea mays L. [BUBH0000006]	Poaceae	Grass	D	jungkham, macrai	Sd	Infusion	1	0.018	Yes, (Kozan *et al.* 2006)
Persicaria hydropiper (L.) Delarbre [BUBH0000029]	Polygonaceae	Herb	W	besongali	L, St	Infusion/ mixture	1	0.018	Yes, (Moyeenul Huq *et al.* 2014; Ayaz *et al.* 2014)
Persicaria strigosa (R. Br.) Nakai [BUBH0000021]	Polygonaceae	Herb	W	alari gwja	L	Raw/ mixture	1	0.018	No
Ziziphus mauritiana Lam. [BUBH0000030]	Rhamnaceae	Shrub	D	bwigri	Lt	Raw /mixture	1	0.018	Yes, (Kone *et al.* 2012)
Morinda citrifolia L. [BUBH0000016]	Rubiaceae	Tree	W	khungkha gwkha	L, R	Decoction	1	0.018	Yes, (Kumar *et al.* 2010), no literature on root
Paederia foetida L. [BUBH0000015]	Rubiaceae	Climber	W	khiphi bendwng	L	Decoction	3	0.055	No
Citrus grandis (L.) Osbeck [BUBH0000064]	Rutaceae	Tree	D	nareng jumra	Fr	Raw	1	0.018	No
Citrus sinensis (L.) Osbeck [BUBH0000049]	Rutaceae	Tree	D	nareng komla	B	Raw/ mixture	1	0.018	Yes, (Rajarajan *et al.* 2009; Gainza *et al.* 2015)

Murraya koenigii (L.) Spreng. [BUBH0000055]	Rutaceae	Shrub	W	nwrsing	L	Raw/ mixture	1	0.018	Yes, (Molla & Bandyopadhyay 2016; Swargiary *et al.* 2016)
Cardiospermum halicacabum L. [BUBH0000001]	Sapindaceae	Herb (Climber)	W	alaishree	L	Raw/ mixture	1	0.018	No
Capsicum frutescens L. [BUBH0000026]	Solanaceae	Herb	D	banlow bwrdwn	Sd	Raw/ Mixture	1	0.018	Yes, (Vinayaka et al, 2010)
Solanum torvum Sw. [BUBH0000018]	Solanaceae	Shrub	W	khunthai nara	Fr	Raw/ mixture	1	0.018	Yes, (Kamaraj *et al.* 2011; Karumari *et al.* 2014)
Lippia alba (Mill.) N.E.Br. ex Britton & P.Wilson [BUBH0000056]	Verbenaceae	Shrub	W	onthai bajab	L	Decoction	2	0.037	No
Tectona grandis L.f. [BUBH0000037]	Verbenaceae	Tree	D	sigun dongfang	L	Raw/ mixture	1	0.018	No
Aloe vera (L.) Burm.f. [BUBH0000022]	Xanthorrhoeaceae	Herb	D	aloe vera	L, Lx	Raw/ Mixture	1	0.018	No
Alpinia nigra (Gaertn.) Burtt [BUBH0000044]	Zingiberaceae	Herb	W	tharai	Lt	Raw/ mixture	1	0.018	Yes, (Roy & Swargiary 2009; Roy *et al.* 2009)
Curcuma caesia Roxb. [BUBH0000008]	Zingiberaceae	Herb	W	haldi gwswm	T	Raw/ mixture	2	0.037	No
Curcuma longa L. [BUBH0000002]	Zingiberaceae	Herb	D	haldi	T	Raw /mixture	2	0.037	Yes, (Bazh *et al.* 2013; Nasai *et al.* 2016)

L- leaves, Lt- tender leaves, Fr- fruits, R- roots, WP- whole plant, B- barks, Lx- latex, T- tuber, St- stem, Sd- seed, Fl- flower. Mode of use is oral in all the plant and its traditional formulations, W – wild, D – domesticated, TF – traditional formulation

However, from 23 other families, only one species was reported. The present study indicates the richness of plants used against helminth infection by the traditional healers of tribal communities of the Kokrajhar district of Assam. It has also been seen that most traditional healers deal with humans, except a few who also deal with livestock such as cows, goats, etc. The survey report also showed that most (58%) of the reported plants are wild in habitats that are not domesticated. Figure 3 shows the number of plant citations. The most commonly used anthelmintic plant was *A. paniculata* with 27 citations, followed by *A. scholaris* (14 citations), *A. comosus* (12 citations), and *A. indica* (10 citations). Out of the reported 64 sp., 43 sp. were mentioned once by the informants. In terms of availability, the survey found that most plants are readily available and accessible to people, except few plants. According to traditional healers, plants like *A. aspera*, *P. bakeri*, *T. trilobatum*, *L. crustacea*, and *R. tetraphylla* were difficult to get.

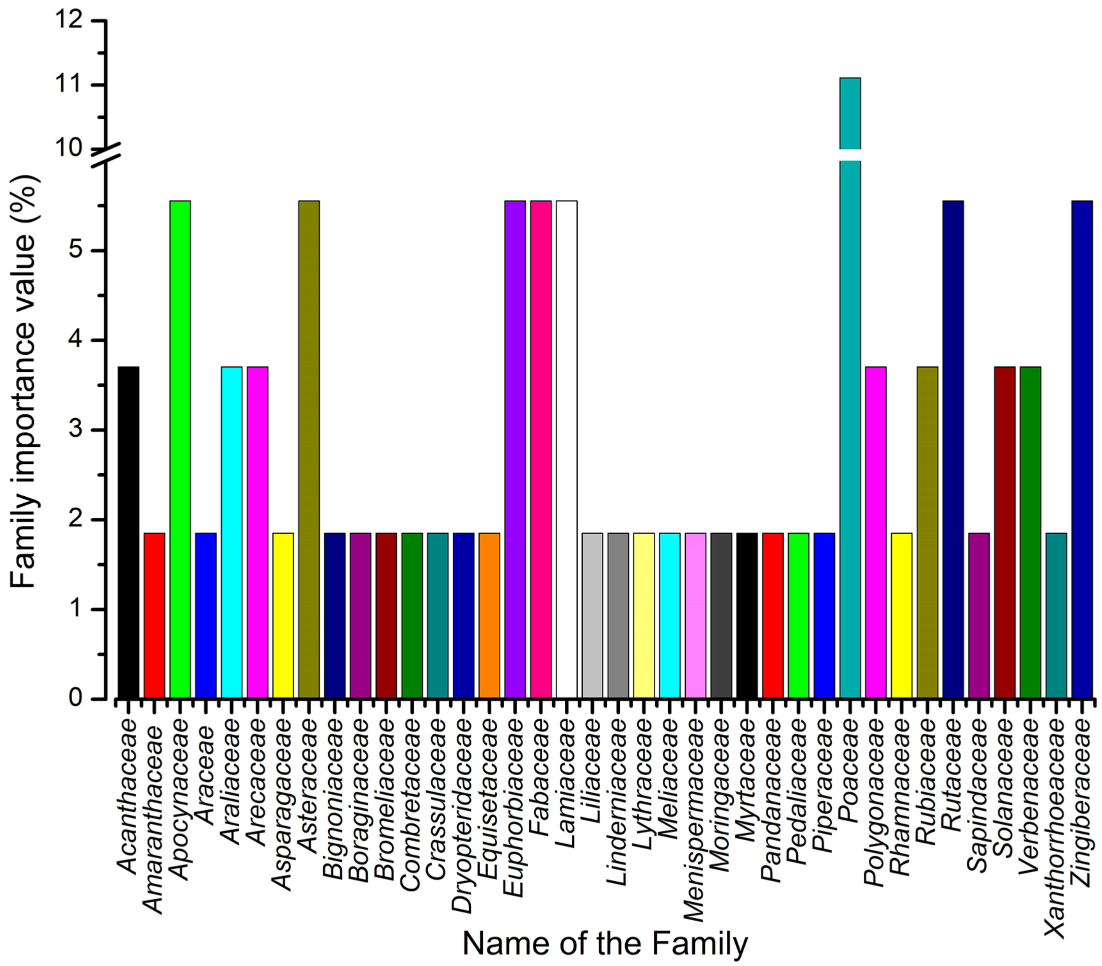

Figure 2. Number of plant families and the relative importance used in the traditional medicinal system by tribal communities against helminthiasis.

Regarding the use of plant parts, leaves were found to be the most commonly used plant parts against helminthiasis. Out of the reported 64 plants, leaves were used in 41 plants to prepare the traditional medicine. Barks, tubers, fruits, roots, and stems were other plant parts commonly used in herbal preparations (Figure 4). In two plant sp. (*E. neriifolia* and *A. vera*), latex was also used for herbal preparation. Out of 41 leaf-use citations, seven citations showed the use of tender leaves for herbal preparations. In two plants, *H. sibthorpioides* and *H. asiatica*, the whole aerial part of the plant is used to prepare the ethnomedicine. In nine plants, more than one part is used to prepare the traditional medicines against helminth infection. It is also observed that the TMs are formulated in five different methods: decoction, infusion, raw, infusion and mixture, and raw and mixture (Figure 4). The process of decoction and infusion is the most common method of TM. Most of the plants reported during the survey were found to be eaten as raw material mixed with other plants or ingredients. The present study also observed that most of the traditional medicines were consumed orally.

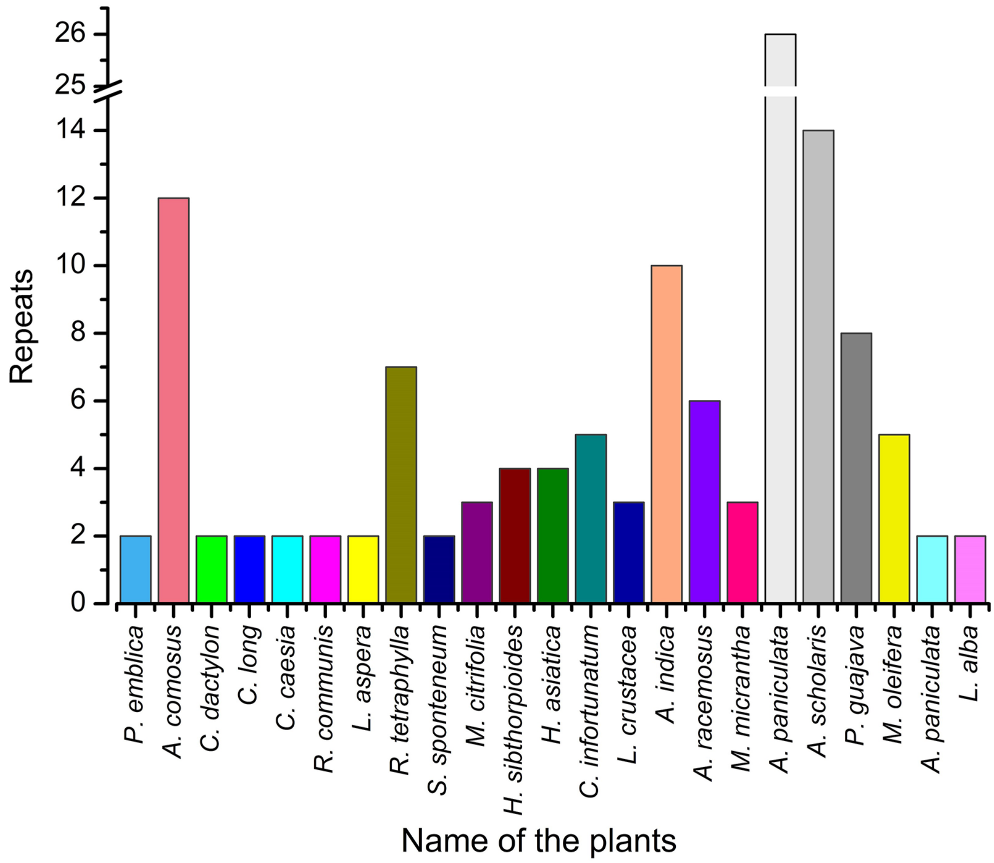

Figure 3. Showing the list of plant citations by village Kaviraja and older people.

Discussion

Plants are a source of natural medicines since ancient times because of their rich phytochemical contents. For ages, people living in rural areas, especially from third-world countries, use plant-based herbal medicines for treating different ailments. Gifted with rich flora and fauna, India is rich in ethnomedicinal knowledge systems. In the present study, putative anthelmintic plants traditionally used by the Bodo community of Kokrajhar district of India were surveyed and documented. Traditional medicine is an essential component of the health care system of most developing countries. Documentation of indigenous use of medicinal plants is important for several reasons. It helps conservation of traditional heritage and biodiversity and also opens up avenues to search for new drugs for diseases (Boadu & Asase 2017). Available literature suggests that the traditional wisdom of ethnomedicine is mainly possessed by aged people. People believe that older people possess more ethnomedicinal knowledge and have more understanding than younger people. The present study also observed that about 74% of the total informants were above 50 years old.

Likewise, many studies also found that the traditional healers are generally above 50 years old (Muthee *et al.* 2011; Baratti-Mayer *et al.* 2019). In our earlier studies, we also observed that most of the informants having anthelmintic ethnomedicinal information from three districts Udalguri, Baksa and Udalguri of BTR, were above 50 years old (Swargiary *et al.* 2019a, b; Swargiary *et al.* 2020). However, most of the time, traditional healers are poor, uneducated and live in the remotest part of the state. Muthee *et al.* (2011) observed that most traditional herbalists from the Loitoktok district of Kenya are illiterate. Of the 11 CDBs, most of the informants from Kokrajhar and Kochugaon CDBs were literate, while informants from other CDBs were mainly illiterate. Meanwhile, the number of plants cited by literate (4.6 plant citations) and illiterate (5.0 plant citations) informants were found to be more or less the same. About 72% of the total informants were professional healers who practice traditional healing daily and earn little money. In comparison, 28% were older knowledgeable people who involve neither in practical traditional healing practice nor money earning process.

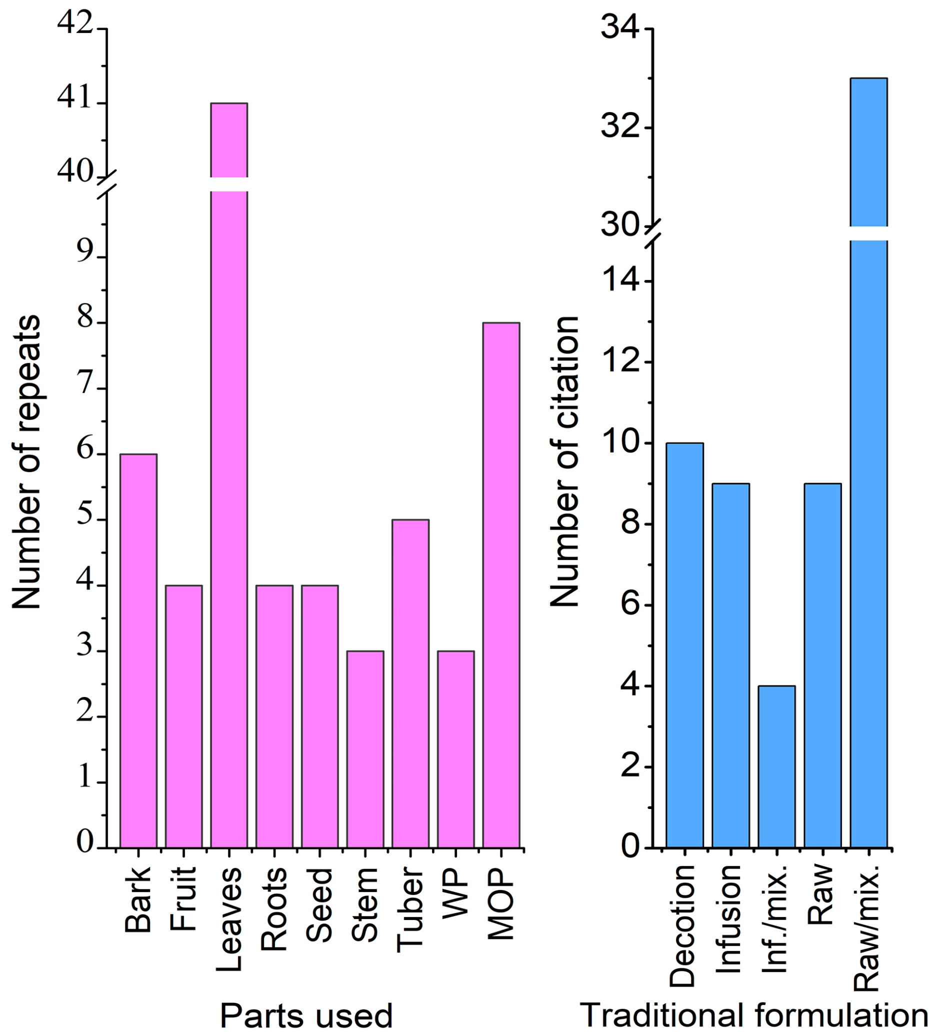

Figure 4. Graph showing (a) the frequency of plant parts used during traditional herbal preparations and (b) types of traditional formulation practices by the tribal communities of Kokrajhar district. WP-whole plant, MOP - more than one part.

The present study shows the richness of plants used in the treatment of helminth infection by the local healers among the Bodo community of the Kokrajhar district. It has also been seen that most traditional healers deal with humans, while a few herbalists also deal with livestock such as cows, goats, etc. Herbal preparations are generally prepared by a mixture of different plants, most commonly, wild in habitat. Our survey report also showed that most (58%) of the reported plants are wild in habitats that are not domesticated. Wintola & Afolayan (2015) also surveyed the anthelmintic plants of Amathole district municipality of the Eastern Cape Province of South Africa, showing Poaceae as one of the most popular anthelmintic plant families. Leaves and roots were found to be the most commonly used parts. It has also come to our observation that most traditional healers do not use any precise and standardised methods of herbal formulation. Based on the nature of the infection, doses of the traditional formulations are also altered. However, in most cases, it has been reported that doses are increased or decreased on the basis of the age of the patient. Furthermore, there was no uniformity in the doses among the informants.

The process of decoction and infusion was the most common method of herbal formulation in the present study. Wintola & Afolayan (2015) also observed similar findings from a study in the Amathole district municipality of the Eastern Cape province, South Africa. Herbal preparations are generally a mixture of several ingredients or plant parts. The present study also observed that more than 56% of the reported plants are consumed orally as raw mixtures with other plants. Many studies have also reported similar results emphasising boiling or soaking in water and drying and grinding as the most preferred methods of the traditional formulation (Teklehaymanot & Giday 2007; Nanyingi *et al.* 2008; Muthee *et al.* 2011). Our survey also found that all the traditional formulations are served and taken through the oral route. Many such ethnomedicinal survey studies have also found similar results (Ndob *et al.* 2016). The oral route of administration is the most common in all the traditional formulations and plants cited.

Available literature suggests that about 50% of the total reported plants have scientific validation about their anthelmintic property that are previously investigated by other researchers. The alcoholic extracts of leaves, barks and seeds of *A. paniculata* were investigated by many researchers showing potent anthelmintic activity (Singh *et al.* 2009; Kamaraj *et al.* 2011; Padma *et al.* 2012). Following our survey findings, the anthelmintic activity of *A. comosus, A. indica, P. guajava, M. oleifera, A. racemosus,* and *C. infortunatum* was reported by (Chagas *et al.* 2008; Das *et al.* 2011; Molla & Bandyopadhyay 2014; Cabardo & Portugaliza 2017). In a recent study, *Alstonia scholaris, Cardiospermum halicacabum, Hydrocotyle sibthorpioides,* and *Hypericum japonicum* were reported to possess substantial in vitro anthelmintic activity (Swargiary *et al.* 2021). The alcoholic leaves extract of *M. citrifolia* have scientific studies for their anthelmintic activity (Kumar *et al.* 2010). The presence of experimental evidence and higher citations of medicinal plants by traditional healers suggest the significance and importance of ethnomedicines.

Conclusions

The present study revealed that the ethnomedicinal knowledge of helminth infection is widespread among the tribal communities of Assam. Although there is rich ethnomedicinal knowledge, most traditional healers do not follow the precise methodology of herbal preparation. Depending on the severity of the diseases, herbal formulations were prepared. The formulations and doses are prepared in the form of the numbers of leaves, fruits, flowers. Therefore, a detailed bioactivity-based study is needed to develop a precise formulation method and better efficacy. The study reported several plants with no scientific validation. Therefore, further study needs to be carried out to explore the bioactivity of the plants.

Declarations

Ethics approval and consent to participate: Not applicable.
Consent for publication: All authors read the final manuscript and approved it for publication.
Availability of data and materials: All data related to the manuscript is present within the paper.
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Authors' contributions: AS designed the work and wrote the manuscript, MD and MK Roy both involved in collecting ethnomedicinal data.

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