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

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Ethnobotany Research & Applications 22:10 (2021)

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
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 is 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 ethnomedical knowledge system can play a significant role. Today, the pharmacological study based on ethnomedical 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 km². 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 ethnomedical 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 'kaviraj 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.), Rupshi (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 biodata, 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):

\[ RFC = \frac{FC}{N} \]

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).

\[ FIV = \left( \frac{FC \ (Family)}{N} \right) \times 100 \]

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.

| Block       | Literacy | Age group | Informants | Total |
|-------------|----------|-----------|------------|-------|
|             | School   | College   | Illiterate | >50   | 40-50 | Kaviraja | Older |       |
| 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   |
|                     | Batpara                         | 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   |
|                     | Latagaoa                        | 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   |
|                     | Shanthhabi                      | 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              | Baghmari                        | 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°39'00.55"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   |
|                     | Movamar                         | 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   |
|                     | Gombaraguri                     | 26°51'13.51"N 90°11'98.16"E   |
|                     | Haldirbari FV                   | 26°36'08.48"N 89°54'08.78"E   |
|                     | Jonailagao 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   |
|                     | Kuntola FV                      | 26°32'55.96"N 90°03'23.55"E   |
|                     | Lotamari FV-II                  | 26°56'89.20"N 90°10'86.83"E   |
|                     | Salbari FV                      | 26°56'56.70"N 90°00'08.17"E   |
|                     | Takampur FV                     | 26°60'29.82"N 90°03'51.70"E   |
|                     | Kathaliguri                     | 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   |
*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 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       | kalmec, 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] | Amarantaceae | 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 asatica* L. [BUBH0000020] | Araliaceae  | Herb      | W       | manimuni gidir   | L, WP Raw/ mixture | 4   | 0.074 | No                                              |
| *Hydrocotyle sibirphoroides* Lam. [BUBH0000019] | Araliaceae  | Herb      | W       | manimuni fisa    | L, WP Raw/ mixture | 4   | 0.074 | No                                              |
| *Calamus tenuis* Roxb. [BUBH0000009] | Arecaceae   | Scandent Shrub | D       | riding bendwng   | L Decoction | 1   | 0.018 | Yes, (Das et al. 2017)                         |
| *Phenix 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)                       |
| *Acmeia 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. [BUBH0000005] | 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                                              |
| Species                          | Family           | Type  | Part | Action | Route | Strength | Reference                                                                 |
|---------------------------------|------------------|-------|------|--------|-------|----------|---------------------------------------------------------------------------|
| Ananas comosus (L.) Merr.       | Bromeliaceae     | Herb  | D    | anaros | Lt    | Infusion/mixture             | Yes, (Hordegen et al. 2006; Domingues et al. 2013; Ahmed et al. 2014)     |
| Terminalia chebula Retz.        | Combretaceae     | Tree  | D    | siliha | Fr    | Raw/mixture                   | Yes, (Dwivedi et al. 2008; Behera & Bhatnagar 2018)                    |
| Bryophyllum pinnatum (Lam.)     | Grassulaceae     | Herb  | D    | paat  | Gaja  | Decoction                     | Yes, (Lunkad et al. 2016)                                             |
| Dryopteris filix-mas (L.) Schott| Dryopteridaceae  | Herb  | W    | sal   | Daokhumwi | Decoction                     | Yes, (Urban et al. 2008)                                              |
| Equisetum debile Roxb. ex Vaucher| Equisetaceae    | Herb  | W    | noljora| St    | Infusion                     | No                                                                         |
| Euphorbia neriifolia L.         | Euphorbiaceae    | Shrub | D    | Sijou  | L, Lx | Raw/mixture                    | No                                                                         |
| Phyllanthus emblica L.          | Euphorbiaceae    | Tree  | D    | Amla  | Fr    | Raw                           | Yes, (Zahir et al. 2012; Mahadev et al. 2017)                           |
| Ricinus communis L.             | Euphorbiaceae    | Shrub | D    | Indi  | L     | Infusion/mixture              | Yes, (Karumari et al. 2014; Meenakshisundaram et al. 2016)              |
| Cassia fistula L. [BUBH0000043] | Fabaceae         | Tree  | W    | Sonalu | L     | Infusion/mixture              | No                                                                         |
| Clitoria ternatea L. [BUBH0000050]| Fabaceae        | Herb  | D    | Neel  | Lt    | Raw/mixture                    | Yes, (Khadatkar et al. 2008; Gollen et al. 2018)                        |
| Sesbania grandiflora (L.) Pers.| Fabaceae         | Tree  | W    | Jayanti| L     | Raw                           | Yes, (Karumari et al. 2014; Meenakshisundaram et al. 2016)              |
| Clerodendrum infortunatum L.    | Lamiaceae        | Shrub | W    | Mwkhwana | L     | Decoction                     | Yes, (Das et al. 2011; Swargiary et al. 2016)                           |
| Leucas aspera (Wild.) Link.     | Lamiaceae        | Herb  | W    | Kansinsa| L     | Raw                           | Yes, (Agarwal et al. 2011)                                             |
| Ocimum sanctum L. [BUBH0000045] | Lamiaceae        | Shrub | D    | Tulungsi (fisa) | L | Raw/Mixture                   | Yes, (Kalarickal et al. 2015; Kanojiya et al. 2015)                     |
| Peliosanthes bakeri Hook.f.     | Liliaceae        | Herb  | W    | Sikho  | T     | Infusion                     | No                                                                         |
| Lindernia crustacea (L.) F.Muell.| Linderniaceae    | Herb  | W    | Na bikhi| L     | Decoction                     | No                                                                         |
| Punica granatum L. [BUBH0000031]| Lythraceae       | Shrub | D    | Dalim | B (root) | Raw                           | Yes, (Aggarwal & Bagai 2017; Yones et al. 2016)                           |
| Azadirachta indica A. Juss.     | Meliaceae        | Tree  | D    | Neem  | L     | Raw/mixture/Decoction         | Yes, (Costa et al. 2006; Chaagas et al. 2008; Iqbal et al. 2010)        |
| Scientific Name          | Family              | Classification | Dosage | Form          | Code | Reference                                                                 |
|--------------------------|---------------------|----------------|--------|---------------|------|---------------------------------------------------------------------------|
| *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      | sofaris, somfreng | Lt  | Raw/ mixture 8 0.148 Yes, (Moll & 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. [BUBH0000024] | Poaceae             | Grass          | W      | engkhwr       | Lt   | Raw/ mixture 1 0.018 No                                                   |
| *Saccharum spontaneum* 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 hydroper* (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      | kphirt bendwing | 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 bwrddwn | Sd | Raw/ Mixture | 1 | 0.018 | Yes, (Vinayaka et al, 2010) |
| Solanum torvum Sw. [BUBH0000018] | Solanaceae | Shrub | W | kunthai 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- 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. schloris* (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. tetraphyla* 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.
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.
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 (Teklehaimanot & Gidaya 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.

Funding: Science and Engineering Research Board, Government of India (File no. EEQ/2017/000071)

Authors’ contributions: AS designed the work and wrote the manuscript, MD and MK Roy both involved in collecting ethnomedicinal data.

Acknowledgement

AS would like to thank SERB, Govt. of India, for providing financial assistance in a research project (Project no. EEQ/2017/000071). Authors are also thankful to the village Kaviraja and older people for providing ethnomedicinal information. Furthermore, we are very much thankful to Dr Sanjib Baruah Asstt. Prof, Department of Botany, for helping in scientific validation of the sample plants.

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