Healing fractured bones -traditional medicinal plants used by Bodo tribe in Bodoland Territorial Area Districts (BTAD) of Assam, India

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Research

Abstract

Background: People of Bodo tribal community are historically reported to be the early settlers of Assam living in the Bodoland Territorial Area Districts (BTAD) region in the Northwestern part of Assam (India) and they have been using plants from their surroundings since the time immemorial for their survival. The present study focused on the medicinal plants used for the treatment of fractured bone by the Bodo people.

Methods: Ethnomedicinal data related to utilization of plants for healing fractured bones were collected through semi-structured interviews of the recognised potential informants. The ethnomedicinal metadata collected was quantitatively assessed to determine Relative Frequency of Citation (RFC), Fidelity Level (FL), and Family Importance Value (FIV).

Results: This study revealed the fractured bone healing knowledge system of the selected informants of Bodo community of BTAD which include 80 male and 80 female informants (n=160) and most of them were possessing long term experienced in treating fractured bone. The present study recorded the use of 46 plant species belonging to 36 families of which Amaryllidaceae, Solanaceae, Lamiaceae, and Zingiberaceae contributed 3 species each, then these are followed by Fabaceae, Malvaceae, Myrtaceae, Piperaceae, and Vitaceae (2 spp. each) and the remaining families are represented by 1 species each. These plants are dominated by annual herbs (12 spp., 26.67%), Geophytes (9 spp., 20%), trees (9 spp., 20%), shrubs (5 spp., 11.11%), climber (3 spp., 6.52% each), small trees, geophytic-climber, epiphyte, perennial herb and aquatic herb (1 sp., 2.17%) each. The leaf was reported as highest plant part harvested (43.48%), which was followed by bark, fruits, and whole plant (8.70% each), and for 6.52% plants it was stem and rhizome. Highest RFC value (0.13125) was observed for *Cissus quadrangularis*, followed by *Equisetum ramosissimum* var. *huegelii* (0.09375), and *Litsea glutinosa* (0.06875). Highest FL has been recorded for *Crinum asiaticum, Gomphostemma* sp., *Aloe vera, Gynura nepalensis, Entada rheedei, Hypericum japonicum, Clerodendrum glandulosum, Hibiscus × rosa-sinensis, Moringa oleifera, Syzygium aromaticum, Persicaria hydropiper, Paederia foetida, Datura metel, Bergera koenigii, Nicotiana tabacum, Thelypteris parasitica,* and *Curcuma*

aromatica are with 100% each. The family Vitaceae has the highest FIV of 14.38%, followed by Equisetaceae (9.35%), and Zingiberaceae (8.125%).

Conclusion: From the study, it has been realized that the native populations of Bodo tribe living in BTAD, Assam is in favor of continuing uses of medicinal plants to treat fractured bones with which they suffer commonly. However, only the elderly people of the Bodo population are culturing and guarding such priceless plant resources and Traditional Knowledge while the younger generation is interested to take modern allopathic way of treatment. It is now important to record the surviving Traditional Knowledge for future scientific evaluation to support the humanity with modern medicines derived from Traditional Knowledge.

Keywords: Ethnomedicinal plants, Bodo tribe, Bone fracture, Healing tradition, BTAD, Assam

Background

Bones in human body provide the basic framework or skeleton to give shape of the body, strengthening it and assist in proper functioning. Any problem on this framework creates numerous problems, especially when there is any dislocation or fracture. A fracture is a condition of complete or incomplete separation in the continuity of the bone (Piermattei 2006). Human body has its own mechanism to heal the fracture and starts functioning in response to any such events. Without causing any change to volume and length of affected bones, fracture healing eventually allows the wounded tissues to reattach and function normally (AI-Aql *et al*. 2008). The histocompatibility and coordination of immune cells inside the bone-marrow play key roles in the process of healing fractures. Mesenchymal stem cells (MSCs) from the surrounding tissues, their circulation, helps to develop skeletal and vascular cell precursors (Gullberg *et al*. 1997; Li *et al.* 2005). Fracture healing is a multi-phase restoration procedure that starts in response to tissue damage and entails intricate, carefully planned processes of the body (Fazzalari 2011) and the entire process is known as 'bone healing' or 'fracture healing' (Singh 2017). There are mainly two types of healing of the fractured bones, that is, primary and the secondary healing process. Primary method of fracture healing can be seen with low callus formation, a direct attempt of bone re-establishes and continuity while it also needs direct contact with cortical cells (Giannoudis *et al*. 2007). The secondary fracture healing of bone could be found in four overlapping phases, (i) formation of hematoma, (ii) setting early inflammation (two to four weeks), (iii) repair (proliferation and differentiation; within a month or two), and (iv) the late remodelling phase (lasting for months or even years) (Harwood *et al*. 2010). The primary healing is rare while majority of the fractured bones are repairs through secondary heating methods (Jahagirdar & Scammell 2009).

Modern medical system in India is a fusion of ancient and contemporary methods, and that depends on historical, cultural, ecological, and socioeconomic aspect of the sufferers (Khan 2006; Kunwar *et al.* 2010). In fact, even today, there are numerous 'fracture healers' who repair fractures using their own traditional methods which include the use of some plant materials. Recent researches in ethnomedicines are essential to record such information that might lead to the discovery of novel compounds for better drug development (Umair *et al*. 2017; Cox 2000). With the recent knowledge on the undesirable side-effects of modern medicines, as well as the high cost of such researches, scientists are now highly inclined to find out plant-derived biomolecules for the preparation of better medicines (Cox & Balick 1994). In fact, globally, the traditional medicines continue to impact larger portion of human population even today (Ahmad *et al*. 1998). Around 60% of the global population and 80% of population in developing countries used plants for medicinal applications (Singh *et al*. 1979; Mshigeni 1990; Dhillion *et al*. 2002). Accordingly, the demand for herbal medicine is rising worldwide, and South Asia's markets are developing at a 20% yearly pace (Srivastava 2000; Subrat 2002). As per the World Bank, commerce in raw materials, botanical drug products, and medicinal plants is expanding at a pace of 5 to 15% annually in the US and Europe, the two largest global markets for crude drugs (Patwardhan *et al*. 2005; Laird & Pierce 2003). Realizing its importance for the health sector, scientists have created workable procedures for identifying the bioactive components of it as well as large-scale synthesis technologies appropriate for the contemporary pharmaceutical industry (Das *et al*. 2021).

The present ethnobotanical study is focused on the medicinal plants and the preparation methods used by the traditional healers of Bodo tribal community to treat bone fractures, what they are practicing since the time immemorial. They are reported to be the early inhabitants in Assam and they are found in the *Bodoland Territorial Area Districts* (BTAD) region of Assam (Endle 1911; CDPS 2004) which is administered by the Bodoland Territorial Council (BTC) (Borthakur *et al*. 2018). The Bodo tribal community of Assam is reported to be rich in traditional knowledge related to utilization of medicinal plants (Basumatary *et al*. 2024a,b). The tribes of Northeast India including the Bodo have the unique methods of practicing their traditional medicinal knowledge (Kotoky & Das 2008; Shankar *et al*. 2012; Basumatary *et al*. 2024a).

Materials and Methods

Study site

The study site, that is, *Bodoland Territorial Area Districts* (BTAD) of Assam (India) is located within the geographical coordinates between the latitude 26°7'12''N to 26°47'50''N and longitude 89°47'40'' E to 92°18'30'' E (Figure 1). The BTAD region of Assam which was created in the year 2003 has a geographical area of 8,970 sq.km, of which 2,562 sqkm (28.6 %) is declared as forest area. Kokrajhar district has the highest geographical area (40%), which is followed by Chirang (28.2%), Baksa (23.3%) and Udalguri (8.5%) (Sarma *et al*. 2008). Almost 90% area of the BTAD is dominated by the Bodo community which is reported as oldest tribal group of Assam (Anonymous 2011). Bodo are found in the Northern Bank of Brahmaputra River sharing boundary with Arunachal Pradesh and Bhutan in the north and endowed with rich tropical forest. The area receives heavy rainfall of up to 1346 mm during North Eastern and South Western monsoon during May to September. Summer is hot and humid (35^{0}C) during day time while winter is mild and pleasant with maximum temperature of 25^{0}C (Anonymous 2011).

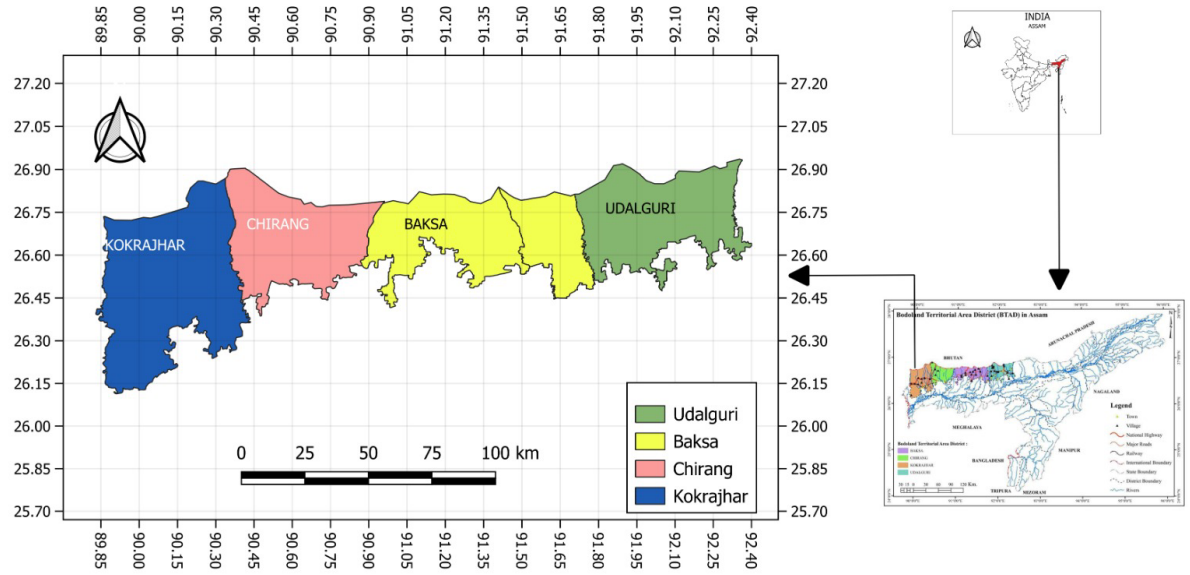

Figure 1. Map showing the four districts of BTAD, Assam, India.

Field survey

The survey of ethnomedicinal plants used for healing of fractured bone in BTAD region of Assam was undertaken during 2022-23 through periodical visits covering all the seasons. Randomly 10 villages (Table 1) were surveyed in each district of BTAD region of Assam. In each village, 02 households were selected and 02 informants were selected from each household were interviewed and their ethnobotanical information was documented (i.e. 10 Villages x 2 Household = 20 Household x 2 informants = 40 informants).

Table 1. Names of villages of four districts of Bodo inhabited BTAD area surveyed for collection of ethnomedicinal plants.

Districts			
Udalguri	**Baksa**	**Chirang**	**Kokrajhar**
Bhurachuburi	No. 1 Nagapara village	Kanthalmuri	Maoriagaon
Bhitwr-Sonai	Mainaopuri	No. 1 Bengthol	ChakrasilaDheerbeel
Amjuli	Swnabdobinjora	Belthari	Dogorphara no. 1
Bor amjuli	Hatidoba	No.2 Saphaguri	New debargaon
Serphang	Hagrabari	South sutharpara	Salani bathabari
Rowta	South Parkijuli	Rangi jora	Semdorpha
Sastrapara	Onthaibari	No. 2 Balapara	Bamunphara
Gola makha	Phangbari	Deolguri	Khunguri
Bornogaon	Sanjahagwjwnpuri	No. 1 Khomabari	Mothambil
Dwifhang	Phangbari	KosubilDaoliguri	Anjaobari

So, in 04 four districts of BTAD, the total of 160 informants were randomly selected and field interview was conducted using standard methods of Martin (1995), Phillips *et al.* (1994), Tag (2007), and Tag *et al.* (2012). Mandatory Prior Informed Consent (PIC) were obtained from key informant prior to the actual field interview. Ethnomedicinal information were gathered through personal interview, focused group discussion and transect walk with key informants in the community forest and home gardens. Questionnaire format for documentation of ethnomedicinal plant data include: (i) Name of villages (ii) informant name, age, and occupation; (iii) vernacular name of plant; (iv) plant parts used; and (v) preparation of medicine, dose and route of administration, and related restrictions if any during healing of fractured bone.

Collection of voucher specimen, identification and preservation

Ethnomedicinal plants used for healing fractured bone were collected during field survey and voucher specimen were prepared by following standard methods (Jain & Rao 1976; Das 2021). Digital photographs were taken for each species using a CANON 1500D camera. Plant species were identified by consulting standard flora such as *The Flora of British India* (Hooker 1872 -1897), *Bengal Plants* (Prain 1903), *Flora of Assam* (Kanjilal *et al*. 1934 -1940), and *Flora of BTAD* (Borthakur *et al*. 2018). Accepted names of the plant species were consulted in the website of POWO (2024) and WFO (2024). Voucher specimens were deposited in the HAU (Herbarium of Arunachal University), Department of Botany, Rajiv Gandhi University, Arunachal Pradesh, India for future consultation.

Quantitative data analysis

The ethnomedicinal plant data related to healing of fractured bone collected from the key Bodo informants during field studies using semi-structured questionnaire format was analysed for various quantitative indices as follows:

i. Relative Frequency of Citation (RFC)

RFC value was calculated to ascertain local importance of every therapeutic plant collected from the study area (Butt *et al*. 2015) using:

$$RFC=FC/N \ (0< RFC < 1)$$

Where, FC=Number of informants who cited the use of the plant species, and
N=Total number of respondents in the survey (N=160).

ii. Fidelity Level (FL%)

Fidelity level is the percentage of respondents who cite and mention using a specific therapeutic plant to treat a particular disorder in the study area. The FL index was calculated using the formula:

$$FL\ (\%) = Np/N \times 100$$ (Friedman *et al*. 1986)

Where, Np=Number of citations of a specific plant for a particular disease, and
N=Total number of informants who cited the species for any disease.

iii. Family Importance Value (FIV)

FIV was calculated from the percentage of respondents citing the family (Kayani *et al*. 2014), as:

$$FIV = FC\ (family)/N \times 100$$

Where, FC is the number of respondents who mentioned the family,
While, N is the total number of respondents participating in the study (N=160)

Results

During the field survey a total of twelve definite formulations of ethnomedicines capable of healing the fractured bones were recorded, each of which include a few species of plants. Also, a total of 46 species (Table 3) has been recorded to be used for these 12 types of herbal formulations. The recorded formulations are presented below along the plant species in use, plant parts harvested, method of preparation and administration of prepared ethno-medicines for treatment of fractured bones.

Formulation 1

According to Rupa Mochahary (daughter) and Burjuli Mochahary (mother) from the Mainaopuri village of Baksa District, 8 plant species are found to be used in their formulation for the treatment of bone fracture. These are -*Musa balbisiana* (leaves)*, Tinospora cordifolia* (stem bark), *Cissus quadrangularis* (whole plant), *Equisetum ramosissimum* var*. huegelii* (whole plant), *Cynodon dactylon* (whole plant)*, Opuntia ficus-indica* (succulent leaves)*, Carica papaya* (leaves)*, Allium sativum* (bulbs)*,* and *Dracaena trifasciata* (leaves)*.* As they informed, different plant-parts (except the leaf of *Musa balbisiana* and stem-bark of *Tinospora cordifolia*) were taken in equal amounts and grinded into a paste on a stone slab. Paste was applied on the fractured part externally, covered with the leaves of *Musa balbisiana,* wrapped with clean cloth and after that the stem bark of *Tinospora cordifolia* was used to tie covered area. The first application was then kept for 3 days and the same was repeated for several times until the positive results could be seen. There is some food-restrictions during the treatment. Patients are not given any meat, sour food and slippery (mucilaginous) foods in favour of proper functioning of the medicine.

Formulation 2

Soti Jiuma Basumatary (wife) and Soken Basumatary (husband) from No. 1 Nagapara village of Baksa District use five different plant species in their medicine viz, *Cissus quadrangularis* (whole plant), *Equisetum ramosissimum* var*. huegelii* (whole plant), *Zingiber officinale* (rhizome)*, Curcuma longa* (rhizome)*,* and *Colocasia esculenta* (leaves)*.* Here, in this method as mentioned by both, all the plant parts of same amount were taken and is grinded on a stone slab to prepare a paste. Following their belief, they chant a prayer or '*mantra'* before applying the paste on the affected area. After smearing the paste, on the affected part of the body, it is then covered with the leaves of *Musa balbisiana* and tied with clean soft cloth sufficient enough to cover the fractured area only. This was then kept for 3 -4 days and repeat the same for 5 -7 times. Patients are not permitted to consume any sour food during the treatment period.

Formulation 3

In formulation prepared for the treatment of bone fracture by Joneth Basumatary [husband] and Joymoti Basumatary [wife] from Swnab Dobinjora village of Baksa district use only four plant species viz, *Cissus quadrangularis* (whole plant)*, Equisetum ramosissimum* var. *huegelii* (whole plant)*, Clerodendrum indicum* (leaves)*,* and *Crinum asiaticum* (leaves). All the plant materials are grinded together into a paste with the help of mortar and pestle. The paste was to be applied on the fractured area, covered it with the help of *Musa balbisiana* leaves*,* and keep the fractured ends in proper position (long enough to cover the area) by pieces of splitted bamboo that are placed round the area and tied properly using soft and clean cloth or cotton gauze bandage. This is to be kept for 3 -4 days and repeated the same till recovery.

Formulation 4

Phwthar Narzary (husband) and Sulmani Narzary (wife) from Maktaigaon village of Kokrajhar district uses five different plant species in their medicine *viz, Entada rheedei* (seeds)*, Tamarindus indica* (leaves), *Zingiber officinale* (rhizome)*, Hibiscus x rosa-sinensis* (flowers)*,* and *Hypericum japonicum* (whole plant)*.* Using a mortar and pestle, all the components were taken together and mashed into a paste**.** Soft clean cloth or cotton gauze-bandage that was just long enough to cover the broken area, just a few centimetres, is used to assist adhering of the plant-paste to the affected area. The first application is to be kept for 4 days. The same process is to be repeated until the condition improves. No sour food and meat are allowed to consume.

Formulation 5

The formulation used by Suraj Basumatary [husband] and Rima Basumatary [wife] from the Maoriagaon village of Kokrajhar district contains only 3 species of plants for the treatment of bone fracture. These are *Cissus quadrangularis* (stem)*, Equisetum ramosissimum* var. *huegelii* (whole plant)*,* and *Litsea glutinosa* (bark)*.* Here, as suggested by the informants, bark of *Litsea glutinosa* is used only to improve adhesiveness of the paste. Plant-parts are grinded into paste by mortar and pestle and the paste is applied on the fractured area, which is then wrapped with the help of soft clean cotton cloth or cotton gauze bandage. This process is repeated in every 3 -4 days till recovery. They did not mention the imposition of any food restriction during the treatment period.

Formulation 6

For the formulation practiced by Sohendra Mochahary [husband] and Sombari Basumatary [wife] from Chakrasila Dheerbeel village of Kokrajhar district use four different ethnomedicinal plants *viz*, *Kalanchoe pinnata* (leaves)*, Litsea glutinosa* (bark)*, Cissus quadrangularis* (stem)*,* and *Zingiber officinale* (rhizome). Plant-parts in equal amounts were taken and washed properly. Which are then ground into a paste and thenapplied on the fracture-affected area. The paste is then covered with the leaves of *Musa balbisiana* and tied properly with clean and thin cotton cloth. The same process is repeated after 3 -4

days till recovery. Here, the bark of *Litsea glutinosa* is used as an adhesive in the paste and *Kalanchoe pinnata* is used for the cooling purpose. Also, they did not mention the imposition of any food restriction during the treatment period.

Formulation 7

Jotish Narzary [husband] and Hiranya Narzary (wife) from Belthari of Chirang district used seven species of plants in their medicine for the treatment of bone fracture, viz. *Litsea glutinosa* (bark)*, Zingiber officinale* (rhizome)*, Capsicum annuum* (fruit)*, Piper longum* (fruits)*, Cissus quadrangularis* (stem)*, Syzygium jambos* (roots)*,* and *Mangifera indica* (roots). Here too, all the plant-parts are washed properly and the required amount is taken, which is then ground properly into the paste and the paste is then covered spread over the affected area, covered with banana (*Musa balbisiana)* leaves and tied properly with thin cotton cloth. It is essential to repeat the same for 6 -7 times in every 3 days. No sour food is permitted to consume.

Formulation 8

In the formulation method depicted by Subash Basumatary [husband] and Alaishree Basumatary [wife] from the Kanthalmuri village of Chirang District a total of four plant species were used, *Cissus quadrangularis* (whole plant)*, Litsea glutinosa* (bark)*, Equisetum ramosissimum var. huegelii* (whole plant)*,* and *Gomphostemma* sp. Plant parts are harvested and dried are grinded into paste and the paste is then covered with *Musa balbisiana* leaves and bound and tied properly with thin cotton cloth. The first application is kept for 3 -4 days and then changed. The same process is repeated in every 3 -4 days till recovery.

Formulation 9

The formula suggested by Momtu Brahma [husband] Sorojoni Brahma [wife] from the Dogorphara no. 1 village of Kokrajhar District, contains five different plants, *viz. Oroxylum indicum* (bark)*, Litsea glutinosa* (bark)*, Bombax ceiba* (roots), *Cissus quadrangularis* (stem)*,* and *Hymenocallis littoralis* (leaves)*.* Different parts of these plants are then grinded along with the feathers of a chick with the help of mortar and pestle. The paste was then applied on the fracture area, covered, and tied properly with the help of thin cotton cloth for 3 -4 days and then changed. The same process is repeated in every 3 -4 days till recovery. There was no restriction on food during the treatment period.

Formulation 10

In drug preparation method suggested by Rone Basumatary [wife] and Ananta Basumatary [husband], from No. 1 Bengthol of Chirang district contains five species of different plants *viz*. *Cissus quadrangularis* (stem)*, Equisetum ramosissimum* var. *huegelii* (whole plant)*, Kalanchoe pinnata* (leaves)*, Gynura nepalensis* (leaves)*,* and *Curcuma longa* (rhizome). These plant parts are then grinded using two pieces of stone and applied on the fractured area. The affected area is then covered with banana (*Musa balbisiana*) leaves. They are tied properly using clean cotton cloth. The first application is to be retained for 2 days and then change in every 2 days, till recovery. Sour food and meat were not allowed to consume during the period of treatment.

Formulation 11

Jiten Swargoyary, from Bhurachuburi of Udalguri District, use 19 different species of plants for the treatment of bone fracture. *Thelypteris parasitica* (leaves), *Clerodendrum colebrookeanum* (leaves)*, Curcuma aromatica* (rhizome)*, Cissus quadrangularis* (leaves)*, Equisetum ramosissimum* var. *huegelii* (whole plant), *Persicaria hydropiper* (leaves)*, Litsea glutinosa* (bark)*, Moringa oleifera* (bark), *Dracaena trifasciata* (leaves)*, Paederia foetida* (leafy-shoot)*, Datura metel* (fruits)*, Aloe vera* (leaves)*, Bergera keongii* (leaves)*, Piper longum* (infructescence)*, Piper nigrum* (fruits)*, Capsicum annuum* (fruit)*, Nicotiana tabacum* (leaves)*, Sygygium aromaticum* (flower-buds), and *Colocasia esculenta* (rhizome). All the plant parts are grinded into a paste, applied on the fractured area and covered with *Musa balbisiana* leaves and then 10 -12 cm long bamboo sticks, called 'sereng', are placed over/around the area and tied properly. The entire area is then covered properly with thin cotton cloth for 3 -4 days. It is then changed many times, till recovery. No sour food, meat, fish or eggs are allowed to consume.

Formulation 12

The eight plants used for the preparation of medicine for bone-fracture by Noara Daimary [husband] and Devi Daimary [wife] from Bhitwr-Sonai village of Udalguri District are *Cissus repens* (stem), *Cissus quadrangularis* (stem)*, Equisetum ramosissimum* var. *huegelii* (whole plant)*, Stephania rotunda* (tuberous root-stock)*, Rhynchostylis retusa* (leaves)*, Hymenocallis littoralis* (leaves)*, Plumbago zeylanica* (leaves)*,* and *Acorus calamus* (leaves)*.* Parts mentioned are grinded into a paste and applied on the fractured area and covered with banana leaves and while tying, they insert a bamboo stick as support to keep the place straight and avoiding any movement. The first application is to be kept for 3 days and regularly change it in every 3 days till recovery.

Demographic characteristics of participants

Equal number of male (80) and female (80) informants were selected and interviewed which was mainly intended to compare the level of traditional healing knowledge and understanding about medicinal plants of their localities. Majority of the respondents (informants) were falling between the age group of 35 -50 (43.125%) year, followed by the above 65 (28.75%) year and 50 -60 (28.128%) year age groups. In this study, 31.87% of the informants were farmers and they are followed by 28.75% of regular Herbal-practitioners, house wives (26.87%), and 12.5% others (Table 1).

Table 2. Demographic data of informants contacted in BTAD area.

Variable	Categories	No. of informants	Percentage
Gender	Male	80	50
	Female	80	50
Age group	35 -50	69	43.125
	50 -65	45	28.125
	Above 65	46	28.75
Occupation	Herbal practitioner	46	28.75
	House wife	43	26.875
	Farmer	51	31.875
	others	20	12.5

Species diversity and habit groups of medicinal plants

This study reported the uses of 46 species of medicinal plants which belonging to 36 families (Table 3, Figure 2). Among the plant families, highest number of species (3 each) were represented in Amaryllidaceae, Solanaceae, Lamiaceae, and Zingiberaceae. This is followed by Fabaceae, Malvaceae, Myrtaceae, Piperaceae, and Vitaceae with 2 species each, while others are with 1 species each. Among the habit and growth form, herbaceous species is represented by highest number of species (12 spp., 26.67%), which is followed by Geophytic herb (9 spp., 20.00%), trees (9 spp., 20.00%), shrubs (5 spp., 11.11%), woody-climber and climber with (3 spp., 6.52% each), small tree, Geophytic climber, epiphyte, perennial herb and aquatic herb (1 sp., 2.17%) each (Figure 3).

Plant parts harvested for preparation of medicines

Leafy parts were found to be frequently plant part harvested (43.48%) for preparation of medicines for bone fracture healing. This is followed by bark, fruits, and whole plant (8.70% each), which was again followed by stem and rhizome (6.52% each), roots, and tuber (4.35%) each, and fruits, seeds, flowers, and bulb (2.17 %) each (Table 3, Figure 4).

Preparation method and administration route

Interestingly, for all the 12 recorded formulations, the prepared medicine is a paste and applied topically. No practitioner prescribes any medicine for consumption. In majority of the cases some restrictions are imposed on the patient during the treatment. Mostly the consumption of sour food, meat, egg, etc. are restricted for the effective treatment.

Relative frequency of citation (RFC)

The RFC values determined in present studies are found to be ranging between 0.00625 and 0.13125 which is presented in Table 3. *Cissus quadrangularis* was recorded with highest RFC value (0.13125). This is followed by *Equisetum ramosissimum* var. *huegelii* (0.09375), *Litsea glutinosa* (0.06875), *Zingiber officinale, Kalanchoe pinnata* (0.05) and *Curcuma longa* (0.025). Plants like *Colocasia esculenta, Aloe vera, Piper longum,* and *Capsicum annuum* were recorded with RFC value of 0.01875 for each, followed by *Acorus calamus, Allium sativum, Mangifera indica, Oroxylum indicum, Carica papaya, Opuntia ficus-indica, Tamarindus indica, Clerodendrum indicum*, *Stephania rotunda, Tinospora cordifolia, Musa balbisiana, Syzygium jambos, Rhynchostylis retusa, Plumbago zeylanica, Cynodon dactylon, Cissus repens* with 0.0125 for each and for the remaining plants species were recorded with RFC value of 0.00625 for each which is lowest.

Table 3. Ethnomedicinal plants used for the treatment of fractured bone by the healers of Bodo community in BTAD of Assam along with their family, Bodo names, habits, parts used, FC, FL, and RFCs. (FC = Frequency of Citation; FL = Fidelity Level; RFC=Relative Frequency of Citation; FIV = Family Importance Value)

Scientific name [Family]; voucher specimen	Bodo name	Habit	Parts used	FC	RFC	FL%	FIV
***Acorus calamus* L.** [Acoraceae]; Udalguri; JB & HT 078(HAU); 27.03.2022	*Bos bilai*	Geophytic herb	Leaf	2	0.00125	50	1.25
***Allium sativum* L.** [Amaryllidaceae]; Udalguri; JB & HT 096 (HAU); 07.04.2022	*Sambram gufur*	Geophytic herb	Bulb	2	0.00125	50	4.37
***Aloe vera* (L.) Burm.f.** [Asphodelaceae]; Udalguri; JB & HT 097(HAU); 05.04.2022	*Aloe vera*	Herb	Leaf	1	0.00625	100	0.625
***Bergera koenigii* L.**[Meliaceae]; Udalguri; JB & HT 057 (HAU); 21.03.2022.	*Morshing Bilai*	Small tree/shrub	Leaf	1	0.00625	100	0.625
***Bombax ceiba* L.**[Malvaceae] Kokrajhar; JB & HT 294 (HAU);17.04.2024	*Sumbli*	Tree	Roots	1	0.00625	50	1.25
***Capsicum annuum* L.** [Solanaceae]; Udalguri; JB & HT-010 (HAU), 07.02.2022	*Banlubwddwn*	Herb	Fruit	3	0.01875	33.33	3.125
***Carica papaya* L.** [Caricaceae]; Udalguri; JB & HT 056 (HAU); 21.03.2022	*Mudumfulbibar*	Tree	Leaf	2	0.0125	50	1.25
***Cissus repens* Lam.** [Vitaceae]; Kokrajhar; JB & HT 270 (HAU); 17.04.2024	*Hat jora(Tinsira)/Mwithakakrong*	Woody climber	Stem	2	0.00125	50	14.38
***Cissus quadrangularis* L.** [Vitaceae]; Kokrajhar; JB & HT 116 (HAU); 11.11.2022	*Haatjora*	climbing or creeping succulent	Stem	21	0.13125	4.76	14.38
***Clerodendrum colebrookeanum* Walp.** [Lamiaceae]; Udalguri; JB & HT 007 (HAU); 03.02.2022	*Mwkhwnajwla*	Shrub	Leaf	1	0.00625	100	1.87
***Clerodendrum indicum* (L.) Kuntze** [Lamiaceae]; Kokrajhar; JB & HT 103 (HAU); 09.10.2022	*Ekhlabir*	Shrub	Leaf	2	0.0125	50	1.87
***Colocasia esculenta* (L.) Schott** [Araceae]; Udalguri JB & HT 008(HAU); 03.02.2022	*Mana thaso*	Geophytic herb	Leaf, rhizome	3	0.01875	33.33	1.85
***Crinum asiaticum* L.**[Amaryllidaceae]; Kokrajhar; JB & HT 295 (HAU); 17.04.2024	*Khanari*	Geophytic herb	Leaf	1	0.00625	100	4.37
***Curcuma aromatica* Salisb.**[Zingiberaceae]; Kokrajhar; JB & HT 296 (HAU); 27.04.2024	*Hagranihaldi*	Geophytic herb	Rhizome	1	0.00625	100	8.125
***Curcuma longa* L.**[Zingiberaceae]; Udalguri; JB & HT-012 (HAU), 10.02.2022	*Haldwi*	Geophytic herb	Rhizome	4	0.025	25	8.125

***Cynodon dactylon* (L.) Pers.** [Poaceae] Kokrajhar; JB & HT 122(HAU); 23.10.2022	*Dabsahagra*	Herb	Whole plant	2	0.0125	50	1.25
***Datura metel* L.** [Solanaceae]; Udalguri: JB & HT 003; 03.02.2022	*Dhatura*	Shrub	Fruit	1	0.00625	100	3.125
***Dracaena trifasciata* (Prain) Mabb.** [Asparagaceae]; Baksa*;* JB & HT 245; 20.10.2022	*Jiboubibar*	Geophytic herb	Leaf	3	*0.01875*	33.33	2.5
***Entada rheedei* Spreng.** [Fabaceae]; Baksa; JB & HT 246 (HAU); 20.10.2022	*Gila thaokri*	Woody climber	Seed	1	0.00625	100	1.87
Equisetum ramosissimum var. ***huegelii* (Milde) Christenh. & Husby** [Equisetaceae]; Kokrajhar; JB & HT 297 (HAU); 20.04.2024	*Nwlwjora*	Herb	Whole plant	15	0.09375	6.66	9.35
***Gomphostemma* sp.** [Lamiaceae]; Udalguri; JB & HT 100(HAU); 20.03.2022	*Saka biphang*	Herb	Leaf	1	0.00625	100	2.5
***Gynura nepalensis* DC.** [Asteraceae]; Baksa; JB & HT 248 (HAU); 20.10.2022	*Daomeowai*	Herb	Leaf	1	0.00625	100	0.625
***Hibiscus × rosa-sinensis* L.** [Malvaceae]; *Baksa;* JB & HT 249 (HAU); 20.10.2022	*Phordophool*	Shrub	Flower	1	0.00625	100	1.25
***Hymenocallis littoralis* (Jacq.) Salisb.** [Amaryllidaceae]; Kokrajhar; JB & HT 298 (HAU); 20.04.2024	*Khanaribilai*	Geophytic herb	Leaf	4	0.00125	25	4.37
***Hypericum japonicum* Thunb.** [Hypericaceae]; Udalguri: JB & HT 053(HAU); 19.03.2022	*Sona phuli*	Herb	Whole plant	1	0.00625	100	0.625
***Kalanchoe pinnata* (Lam.) Pers.** [Crassulaceae]; Kokrajhar; JB & HT 299 (HAU); 20.04.2024	*Paat gaja*	Herb	Leaf	4	0.025	25	2.5
***Litsea glutinosa* (Lour.) C.B.Rob.**[Lauraceae]; Kokrajhar; JB & HT 300(HAU);20.04.2024	*Bagh naal*	Tree	Bark	11	*0.06875*	9.1	6.88
***Mangifera indica*L.** [Anacardiaceae]; JB & HT 043 (HAU); 09.04.2022	*Thaijou*	Tree	Root	2	0.0125	50	1.25
***Moringa oleifera* Lam.** [Moringaceae]; Udalguri; JB & HT 067 (HAU); 23.03.2023	*Mwdwi*	Tree	Bark	1	0.00625	100	0.625
***Musa balbisiana* Colla** [Moraceae]; Kokrajhar; *JB & HT* 148 (HAU); 02.02.2023	*Thalir athia*	Perennial herb	Leaf	2	0.0125	25	1.25
***Nicotiana tabacum* L.** [Solanaceae]; Kokrajhar, Othaigaon, JB & HT- 139 (HAU); 23.11.2022	*Sada*	Herb	Leaf	1	0.00625	100	3.125
***Opuntia ficus-indica* (L.) Mill.** [Cactaceae]; Baksa; JB & HT 247(HAU); 20.10.2022	*Cactus like*	Shrub	Leaf	2	0.0125	50	1.25

***Oroxylum indicum* (L.) Kurz** [Bignoniaceae]; Udalguri; JB & HT-036 (HAU); 08.04.2022	*Bagnalabigur*	Tree	Bark	2	0.0125	50	1.25
***Paederia foetida* L.** [Rubiaceae]; Udalguri: JB & HT 055(HAU); 20.03.2022	*Khipibendwng*	Woody climber	Whole plant	1	0.00625	100	0.625
***Persicaria hydropiper* (L.) Delarbre.** [Polygonaceae]; Udalguri; JB & HT 071(HAU); 22.03.2022	*Desongaligwja*	Aquatic herb	Leaf	1	0.00625	100	0.625
***Piper longum* L.** [Piperaceae]; Udalguri; JB & HT-033 (HAU); 03.03.2022	*Asira jwla/salGolmoris*	Climber	Infructescence	3	0.01875	33.33	2.5
***Piper nigrum* L.** [Piperaceae]; Udalguri; JB & HT-028 (HAU); 02.03.2022.	*Gol moris*	Climber	Fruit	1	0.00625	100	2.5
***Plumbago zeylanica* L.** [Plumbaginaceae]; Kokrajhar; JB & HT 282(HAU); 18.04.2024	*Agwi ashi*	Herb	Leaf	2	0.0125	50	1.25
***Rhynchostylis retusa* (L.) Blume** [Orchidaceae]; Udalguri; JB & HT 099 (HAU); 20.03.2022	*Manla phul(Kopouphul)*	Epiphytic	Leaf	2	0.0125	50	1.25
***Stephania rotunda* Lour.** [Menispermaceae]; Udalguri; JB & HT-015 (HAU); 21.05.2022	*Bilaidulur, swima kunturi, dumaolu bedor*	Geophytic climber	Tuber	2	0.0125	50	2.5
***Syzygium aromaticum* (L.) Merr. &L.M.Perry** [Mytraceae]; Udalguri; JB & HT 014 (HAU); 20.04.2022	*Luang*	Tree	Flower bud	1	0.00625	100	1.87
***Syzygium jambos* (L.) Alston** [Myrtaceae] Kokrajhar; JB & HT 286 (HAU); 18.04.2024	*Boga jam*	Tree	Root	2	0.0125	50	1.25
***Tamarindus indica* L.** [Fabaceae]; Udalguri; JB & HT 091(HAU); 24.02.2022	*Bis thinkhlang*	Tree	Leaf	2	0.0125	50	1.87
***Thelypteris parasitica* (L.) Tardieu** [Aspleniaceae]; Kokrajhar; JB & HT 125(HAU); 23.11.2022	*Dingkhiabaola*	Herb	Leaf	1	0.00625	100	0.625
***Tinospora cordifolia* (Willd.) Hook.f. & Thomson.** [Menispermaceae]; Udalguri; JB & HT-040 (HAU); 09.03.2022	*Amor lota*	Woody climber	Stem bark	2	0.0125	50	2.5
***Zingiber officinale* Roscoe** [Zingiberaceae]; Kokrajhar; JB & HT 300 (HAU); 27.04.2024	*Haizeng*	Geophytic herb	Rhizome	8	0.05	12.5	8.125

Fidelity level (FL %)

The higher values of fidelity level (FL) recorded for some species of medicinal plants indicate that these species are frequently used for the treatment of fractured bone. The FL values recorded in present studies were found to be ranging between 6.66% to 100% which is presented in Table 3. The highest FL value of 100% each has been recorded for *Crinum asiaticum* L., *Gomphostemma* sp., *Aloe vera, Gynura nepalensis, Entada rheedei, Hypericum japonicum, Clerodendrum colebrookeanum, Hibiscus × rosa-sinensis, Moringa oleifera, Syzygium aromaticum, Persicaria hydropiper, Paederia foetida, Datura metel, Bergera koenigii, Nicotiana tabacum, Thelypteris parasitica, Curcuma aromatica*. These are then followed by *Acorus calamus, Allium sativum, Mangifera indica, Oroxylum indicum, Carica papaya, Syzygium jambos, Opuntia ficus-indica, Tamarindus indica, Clerodendrum indicum*, *Stephania rotunda, Bombax ceiba, Moringa oleifera, Rhynchostylis retusa, Plumbago zeylanica, Cynodon dactylon,* and *Cissus repens* with recorded FL value of 50% each. Plants like *Colocasia esculenta, Dracaena trifasciata, Piper longum,* and *Capsicum annuum* were recorded with FL value of 33.33% each while *Hymenocallis littoralis, Kalanchoe pinnata,* and *Curcuma longa* with (25%) each, and the remaining plants, *viz*. *Zingiber officinale* (12.5%), *Litsea glutinosa* (9.1%) and *Equisetum ramosissimum* var. *huegelii* (6.66%) were recorded with very low FL values which implies their less frequent application.

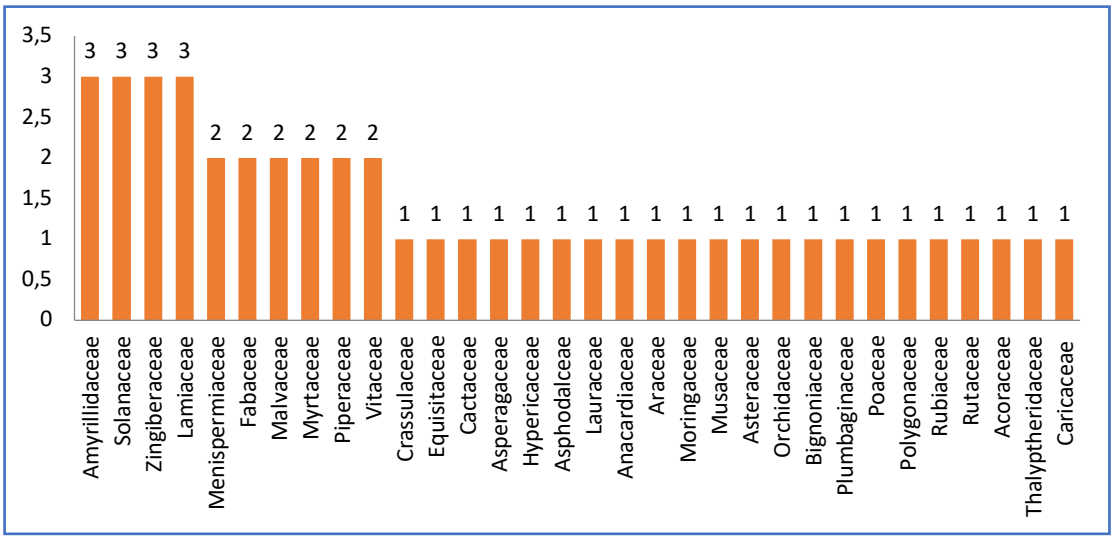

Figure 2. Graph showing the number of species in each plant family.

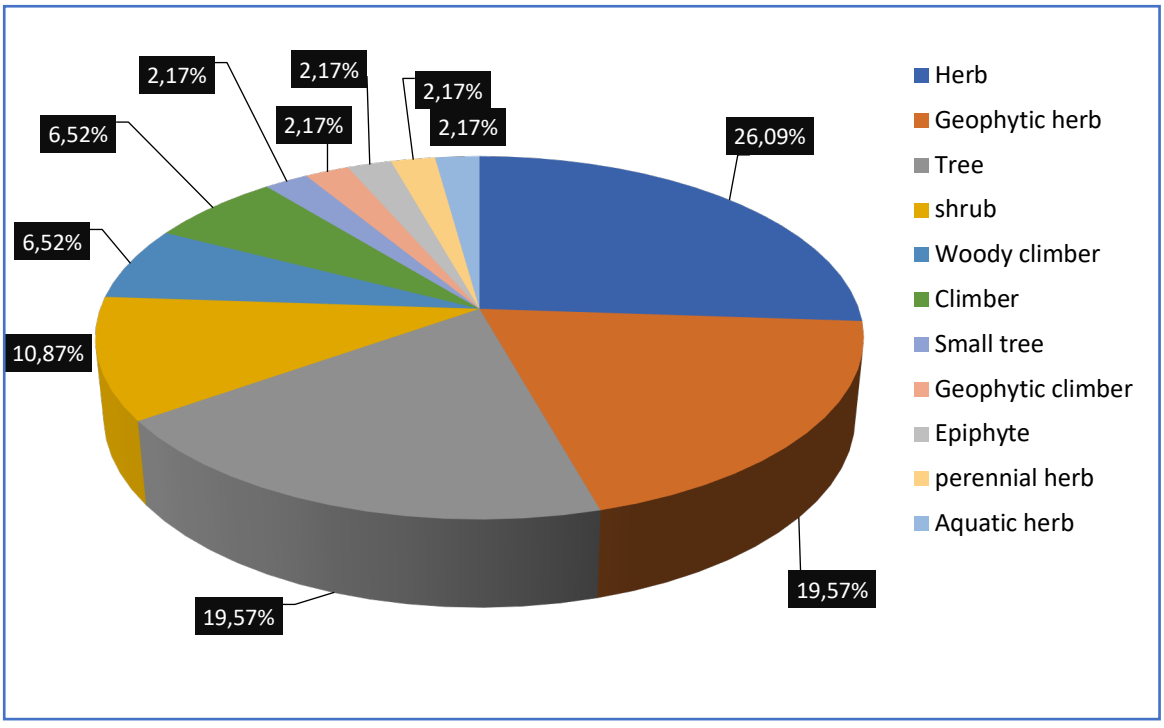

Figure 3. Graph showing habit frequency of bone healing plant species recorded from BTAD, Assam, India.

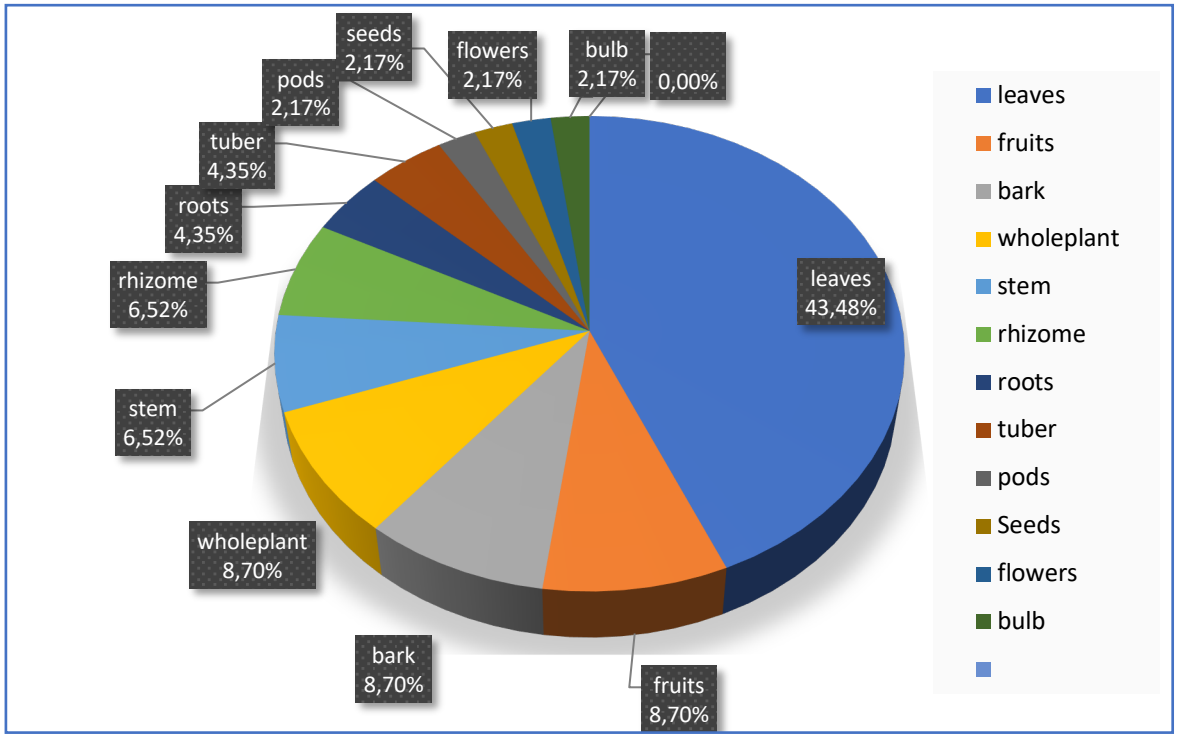

Figure 4: Graph showing percentage of plant-parts used for the preparation of herbal formulation for treatment of fractured bones among the Bodo healers of BTAD.

Family Importance Value (FIV)

The Family Importance Value (FIV) tend to increase with the increase in the frequency of citations of plant species belonging to a particular family (Table 4). The family Vitaceae has the highest FIV of 14.38%, followed by Equisetaceae (9.35%), and Zingiberaceae (8.125%); while the lowest FIV was reported for Acoraceae (0.625%).

Table 4. Family importance value (FIV) of the ethnomedicinal plant species and families recorded in the BTAD, Assam.

Family Name	No. of species	FC (Family)	FIV
Acoraceae	1	2	1.25
Amaryllidaceae	3	7	4.37
Anacardiaceae	1	2	1.25
Araceae	1	3	1.87
Asparagaceae	1	3	1.87
Asphodelaceae	1	1	0.625
Asteraceae	1	1	0.625
Bignoniaceae	1	2	1.25
Caricaceae	1	2	1.25
Crassulaceae	1	4	2.5
Equisetaceae	1	15	9.35
Cactaceae	1	2	1.25
Fabaceae	2	3	1.87
Hypericaceae	1	1	0.625
Lamiaceae	3	4	2.5
Lauraceae	1	11	6.88
Malvaceae	2	2	1.25
Menispermaceae	2	4	2.5

Moringaceae	1	1	0.625
Musaceae	1	2	1.25
Myrtaceae	2	3	1.87
Orchidaceae	1	2	1.25
Piperaceae	2	4	2.5
Plumbaginaceae	1	2	1.25
Poaceae	1	2	1.25
Polygonaceae	1	1	0.625
Rubiaceae	1	1	0.625
Rutaceae	1	1	0.625
Solanaceae	3	5	3.125
Aspleniaceae	1	1	0.625
Vitaceae	2	23	14.38
Zingiberaceae	3	13	8.125

Discussion

Present survey has documented 46 species of ethnomedicinal plants belonging to 36 plant families from the BTAD region of Assam. The informants include equal number of male and female herbal practitioners indicating that the Bodo tribe confers equal opportunity to both the genders of their community to practice traditional medicines for human welfare. Among the total informants recorded, the highest number of informants were recorded under the age group of 35 -50 years. This indicates that the younger generation of middle age category of Bodo tribe has the higher motivation to learn bone healing related traditional knowledge of their ancestors which is similar with previous reports of Adela *et al*. (2020), and Jalil *et al*. (2012). The most dominant plant families recorded are Amaryllidaceae, Solanaceae, Lamiaceae and Zingiberaceae with three species each. The growth forms used to treat bone fracture were mainly the herbs (19 spp., 41.30%). Abbasi *et al*. (2013) and Saxena *et al*. (2014) also reported maximum use of herbaceous species for bone healing. Herbaceous plants contain many bioactive compounds such as flavonoid and phenolic compounds of anti-oxidant, wound healing and other therapeutic activities (Mesfin *et al*. 2009; Adnan *et al.* 2014; Adnan *et al*. 2014; Lulekal *et al*. 2013). Leafy part was found to be the highest plant part (43.48%) harvested and use for treatment of fractured bone due to accessibility and easy in preparations of medicines as paste or tincture when compared to the other plant parts. For this reason, leaves are frequently used in different herbal medicines (Telefo *et al*. 2011; Kadir *et al*. 2013). Previous studies also reported leaves to be most frequently plant part harvested and used to treat bone fracture (Vinayak *et al*. 2012; Sheelawati *et al.* 2013; Ram *et al*. 2024). The present study also noted that all the informants and traditional healers use a single mode of preparation i.e. a paste to treat the medicine for bone-fracture and the mode of administration was only topical, which has been corroborated by Ram *et al*. (2024).

Highest RFC (0.13125) was recorded for *Cissus quadrangularis* which reflects the medicinal significance of the species for treatment of fractured bone among the Bodo community. Fidelity Level was used to determine the preferences for a therapeutic plant by the local inhabitants for the treatment of a particular ailment. However, Vitaceae has been recorded with highest FIV of 14.38% during the present study.

Cissus quadrangularis of Vitaceae was found to be in the highest use in all types of formulations recorded. This indicate that traditional Bodo healers consider *Cissus quadrangularis* as an important species playing a crucial role for healing bone fractures. The positive influence of this plant was also previously reported in many studies as wound healer (Kirtikar & Basu 1935; Kumar 2002; Kayang 2007; Kurian 2009). Higher level of calcium and phosphorus and phytoestrogenic property reported in *Cissus quadrangularis* might be attributed to increase in bone mass and fastening bone healing (Pan *et al.* 2011). Patnaik *et al*. (2007) was also of the opinion that presence of vitamins and steroid in *Cissus quadrangularis* might stimulate the cells of mesenchymal origin which contribute to fast healing. *Tinospora cordifolia* extracts was also reported to be effective against healing of fractured bone (Rao 1981; Simon 1996; Singh 2011; Sofowora 2008).

Conclusion

Now-a-days, modern medical treatments are generally used to address fractured bone in urban and semi-urban areas where such facilities are available. Such modern facilities are present in all the four districts of BTAD, but for the rural poor people living in far-flung areas, the local traditional treatments are easily available and on which they are reposing faith for generations. However, treatments given by the traditional healers are cheap, and affordable as they use only locally available plants with no side effects. In facts, suffering from bone-fracture is quite common as the rural people need to work in different hazardous occupational conditions throughout the day including agriculture and forest tracking. The selected combination of plants heals the fractures with satisfaction to the sufferers.

Declarations

List of abbreviations: Relative Frequency of Citation (RFC), Fidelity Level (FL), and Family Importance Value (FIV).
Ethics statement: Before the survey, we obtained Prior Informed Consent from each participant.
Consent for publications: All authors read and agreed on the publication of the final manuscript.
Funding: NFST, Ministry of Tribal Affairs, Govt. of India.
Conflicts of interest: The authors declare that there are no conflicts of interest in this article.
Availability of data and materials: The figures and tables are provided with proper captions, and the original data sets in excel format are available with the first author upon request.
Authors' contributions: Field survey and the first draft of manuscript was prepared by Jenima Basumatary. Rinchin Norbu Thungon and Pakgam N Lendo contributed in plant identification, statistics and initial draft of manuscript. Abhaya Prasad Das, Pallabi Kalita Hui and Hui Tag contributed in research design, concept, plant identification, supervision, manuscript editing and final communication of this work.

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