

## An ethnobotanical survey of antidiabetic medicinal plants used by the Bodo tribe of Kokrajhar district, Assam

Manita Daimari<sup>1</sup>, Mritunjoy Kumar Roy<sup>1</sup>, Ananta Swargiary<sup>\*1,+</sup>, Sanjib Baruah<sup>2</sup> & Sanswring Basumatary<sup>2</sup>

<sup>1</sup>Department of Zoology, Bodoland University, Debargaon, Kokrajhar, Assam 783 370, India

<sup>2</sup>Department of Botany, Bodoland University, Debargaon, Kokrajhar, Assam 783 370, India

E-mail: <sup>+</sup>ananbuzoo101@gmail.com

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Diabetes mellitus (DM) belongs to the group of diseases causing major health problems in India and world at large. Natural products including medicinal plants are known to treat various diseases worldwide since ancient times. It is well known that plants are a great source of bioactive compounds having tremendous medicinal properties and can be used to discover plant-based drugs with lesser side effects. A survey was carried out among the Bodo community of Kokrajhar district of Assam to explore the traditional knowledge on medicinal plants against diabetes using semi-structured interviews among the local healers and elderly people. A total of 54 informants were interviewed in a face-to-face manner following readymade questionnaire, of which 15 healers were known to have knowledge regarding antidiabetic medicinal plants. A total of 37 medicinal plants, belonging to 24 families and 33 genera were found to be used by traditional healers of Kokrajhar district to cure diabetes. The mostly cited plant was found to be *Hodgsonia heteroclita* (Roxb.) followed by *Andrographis paniculata* (Burm. f.) Nees. Out of the 24 families, Apocynaceae was found to be the most popular plant family with four numbers of plants.

**Keywords:** Antidiabetic, Bodo tribe, Ethnomedicine, Kokrajhar

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The world is fertile with natural and medicinal plants. Medicinal plants continue to be an important therapeutic aid for alleviating ailments of mankind<sup>1</sup>. Approximately 80% of the people in the developing countries rely on traditionally used medicinal plants for their primary health care needs<sup>2</sup>. Plants have always been an exemplary source of drugs since ancient times. Many of the currently available drugs have been derived directly or indirectly from plant source<sup>3</sup>. Plants are a rich source of bioactive compounds (secondary metabolites) and are of great value for developing novel therapeutic agents<sup>4</sup>. Since ancient times, plants and its derivatives have been traditionally used as medicine for the treatment of various diseases. Many plants such as *Tylophora indica*, *Dioscorea bulbifera* etc. are used for the treatment of common health problem such as asthma, piles, dysentery, etc<sup>5</sup>.

DM is a metabolic disorder characterized by hyperglycemia resulting from defects in either insulin secretion or insulin resistance or both<sup>1</sup>. There are two

major forms of diabetes- Type-1 (insulin-dependent DM) and Type-2 (noninsulin-dependent DM). Type-I DM occurs when the human immune system destroys pancreatic  $\beta$ -cells, which are responsible for secreting insulin. Insulin concentration can efficiently be managed through continuous injection in timely dosages. Elevated post-prandial blood glucose levels are widely recognized as one of the earliest disease markers in the prediction of subsequent microvascular and macrovascular complications that can progress to full symptomatic Type-2 Diabetes (T2DM). Type-2 DM accounts for about 90% of the diabetic cases and typically begins as insulin resistance until the pancreas slowly loses its ability to produce insulin<sup>6</sup>. Globally, an estimated of 422 million adults were living with diabetes in 2014, rising from 4.7% to 8.5% in adult population<sup>7</sup>. It is the most common and very prevalent disease affecting the citizens of both developed and developing countries all around the world. It is estimated 25% of the world's population is currently being affected by this disease<sup>8</sup>. Currently available therapy for diabetes and the use of orthodox drugs in the management of DM

\*Corresponding author

has not improved the situation but are reported to produce serious adverse side effects such as liver problems, lactic acidosis and diarrhoea. Plants are well known in traditional medicine for their hypoglycaemic activities. Available literature indicates that there are more than 800 plants species showing hypoglycaemic activity<sup>9</sup>. There has been increasing demand for the use of plant products with antidiabetic activity due to low cost, easy availability and lesser side effects<sup>1</sup>. Currently medicinal plants continue to play an important role in the management of diabetes mellitus. Recently, the World Health Organization (WHO) recommended the use of medicinal plants for the management of DM and further encouraged the expansion of the frontiers of scientific evaluation of the hypoglycaemic properties of diverse plant species<sup>10</sup>.

North east India is blessed with rich flora and fauna. The favourable climate condition in this part of India, provide various endemic plants and animals to sustain their lives, making it the biodiversity hot spot area. It comprises of eight states viz; Arunachal Pradesh, Assam, Manipur, Meghalaya, Mizoram, Nagaland, Sikkim and Tripura. Bodoland Territorial Council (BTC) consist of areas located in extreme north of north bank of river Brahmaputra in the state of Assam, at the foothills of Bhutan and Arunachal Pradesh. It is the gateway to the north eastern region of India, which was created in February, 2003 by curving eight districts out of Assam namely Kokrajhar, Dhubri, Bongaigaon, Barpeta, Nalbari, Kamrup, Darrang and Sonitpur within the state of Assam. Geographically, it covers an area of 8,795 sq. km (provisional) that includes Bodoland Territorial Area Districts administered by the BTC, an autonomous administrative unit constituted under the sixth schedule of constitution<sup>11</sup>. This part of India is full of medicinal plants. Several medicinal plants are traditionally being used as medicines against many diseases. Although a large number of plants are used as medicine, no scientific work has been carried out comprehensively in this part of India. Keeping this view in mind, the present study has been designed to study the medicinal plants traditionally being used as antihyperglycemic agent by the Bodo people of Kokrajhar district of Assam.

### Materials and methods

A survey was carried out in Kokrajhar district which is predominantly inhabited by the Bodo tribe,

and covers an area of 3169.22 km<sup>2</sup>, geographical location of 89°46' East to 90°38' East and 26°19' North to 26°54'North. It is located in the extreme north of the river Brahmaputra, and is rich in various flora and fauna. For administrative purpose, the district is divided into 11 Community Development Blocks (CDBs) and has a total of 1068 villages, of which 15 is uninhabited forest villages. The names of CDBs are: (1) Kachugaon, (2) Gossaigaon, (3) Hatidhura, (4) Dotma, (5) Kokrajhar, (6) Golakganj, (7) Rupsi, (8) Debitola, (9) Mahamaya, (10) Bilasipara and (11) Chappar-Salkocha.

The survey was done from the month of April to October 2018. The demographic data and information about the medicinal plants was collected with the help of local healers and elderly people having knowledge about medicinal plants. Within every CDB, approximately 20 adjacent villages were taken as single cluster and one sample is collected from a cluster. The information was collected via the administration of semi-structured interviews with the help of ready-made questionnaire. The information collected from informants included informer's bio-data, name of the plant, parts used, traditional formulation processes and mode of administration. A total of 54 traditional healers were interviewed from different villages of Kokrajhar district but only 15 informants were found to have knowledge regarding medicinal plants used for the treatment of diabetes. The medicinal plants mentioned by the herbalist were photograph and collected for identification. Herbarium sheets were prepared and submitted to the Department of Botany, Bodoland University, the identification numbers were collected and the voucher specimen were preserved.

### Data analysis

All the statistical calculations, graphs etc. were carried out in Microsoft excel and Origin software. The documented data was analysed by comparing a number of parameters such as number of plant species, families, plant part used, modes of utilization, habit and habitat of the plant species.

### Results and discussion

In the present study 54 local healers were interviewed from 54 different villages of 11 CDBs under Kokrajhar district. However, only 15 informants were found to possess ethnomedicinal knowledge regarding the antidiabetic medicinal plants

as well as other common diseases. Out of the 15 informants, 11 were male and 4 were female. The names of the CDBs, Informant's villages and their geographical locations are given below in Table 1. Out of the 15 informants, the highest numbers of informants were recorded from Kokrajhar CDB followed by Dotma and Gossaigaon. Fig. 1 represents the different locations of information collection sites.

Regarding literacy, it is found that most of the informants (40%) were having school level education, while 33.3% have college level education, and 20% has no formal education at all (Table 2). Similarly, many such ethnomedicinal survey reports have revealed that traditional knowledge bearers are always illiterate, poor and rural based livelihood<sup>63,64</sup>. Regarding the ethnomedicinal knowledge literate

Table 1 — List of villages where antidiabetic medicinal plants were collected along with the geographical location

Sl no	C.D. Block	List of villages	Geographical location
1.	Chapar- Salkocha	Borghola	26°17'04.23"N 90°18'20.32"E
2.	Dotma	Baoraguri	26°27'07.21"N90°08'36.27"E
3.		Dotma Bazar	26°28'06.81"N 90°09'02.61"E
4.		Narenguri	26°29'19.30"N 90°05'23.74"E
5.	Kachugaon	Karikhar FV	26°32'47.01"N 90°03'35.05"E
6.		Kumtola FV	26°33'06.04"N 90°02'55.13"E
7.	Kokrajhar	Chilaguri	26°28'35.26"N 90°12'04.06"E
8.		Mahendrapur	26°36'09.86"N 90°14'24.07"E
9.		Mawriagaon-II	26°27'04.83"N 90°08'40.14"E
10.		Pakhriguri	26°31'00.58"N 90°14'32.44"E
11.		Sutharpara	26°29'36.69"N 90°20'38.95"E
12.	Gossaigaon	Banglabari	26°39'05.55"N 90°03'27.32"E
13.		Gossaigaon-I	26°42'84.87"N 89°99'98.33"E
14.		Singimari-II	26°36'04.09"N 89°99'01.02"E
15.	Debitola	Kazigaon Pt.-I	26°19'21.79"N 89°99'46.81"E

\*Part (Pt.) means some villages of Debitola CDB comes under Dhubri district and some under Kokrajhar district and the villages that come under Kokrajhar district is written as 'Part'. FV - forest village.

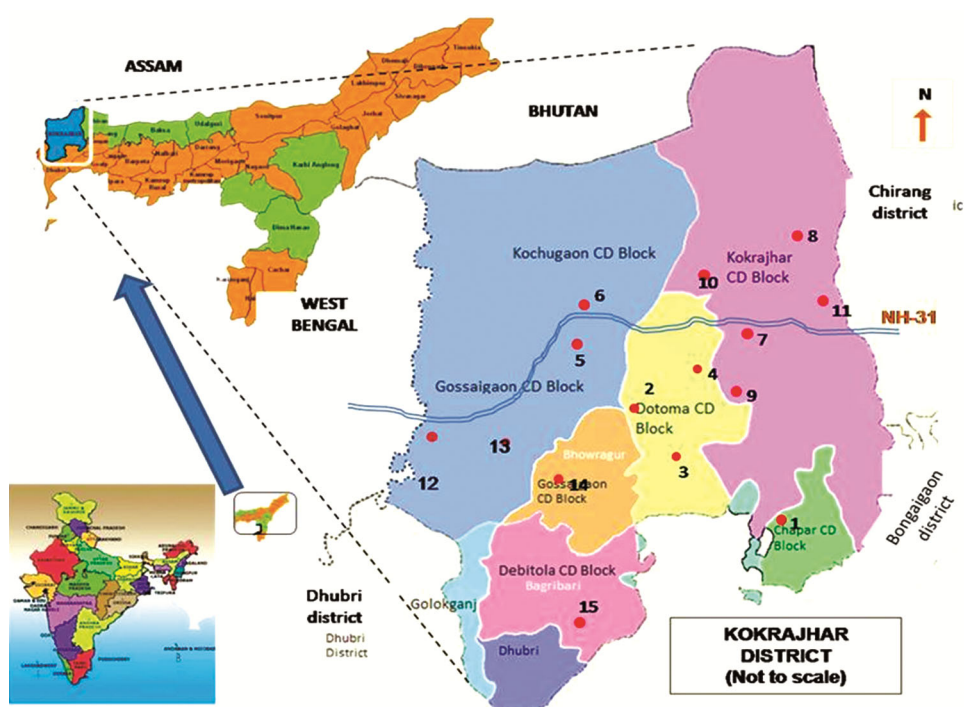


Fig. 1 — Map showing geographical locations of informants of 11 CDB of Kokrajhar district

traditional healers were found to possess more information (4.8 plant citations/informants) than illiterates (2.3 plant citations/informants). All the

informants were local healers, who had been practicing traditional medicine system since long times. It has also been found that most of the knowledge about the medicinal plants has been passed onto them by their parents or grandparents or some relatives who had a vast knowledge about the diseases and its cure. The names of the plant species, its local names as well as the traditional formulation methods is shown in Table 3. Our survey revealed that 37 species of medicinal plants belonging to 24 families and 33 genera are found to be used for the treatment of diabetes. Our survey also found that, most of the plants cited by the local healers are locally available,

Table 2 — Demographic characteristics of informants of Kokrajhar district CDBs

Block	School	College	Illiterate
Chapar-Salkhocha	1	-	-
Dotma	2	1	-
Debitola	1	-	1
Gossaigaon	1	1	1
Kokrajhar	1	3	-
Kachugaon	1	-	1
<b>Total</b>	<b>7</b>	<b>5</b>	<b>3</b>

Table 3 — Name of the plants, parts used, traditional formulation and habit of plants

Sl. No.	Scientific Name & Voucher Number	Family	Local Name (Bodo)	Parts Used	Preparation	Habit	References
1.	<i>Tinospora cordifolia</i> (Willd.) Meirs [BUBH2018024]	Menispermaceae	amar lotha	stem, leaves	decoction	climber	Yes <sup>12-14</sup>
2.	<i>Phyllanthus emblica</i> L. [BUBH2018023]	Euphorbiaceae	amla	fruit	raw	tree	Yes <sup>15,16</sup>
3.	<i>Terminalia arjuna</i> (Roxb. Ex DC.) Wigt & Arn [BUBH2018066]	Combretaceae	arjun	bark	infusion	tree	Yes <sup>17,18</sup>
4.	<i>Musa balbisiana</i> Colla [BUBH2018067]	Musaceae	athia thalir	aerial stem	decoction	shrub	No
5.	<i>Phlogacanthus tubiflorus</i> Nees [BUBH2018028]	Acanthaceae	basikhor	flower	decoction	shrub	NO
6.	<i>Aegle marmelos</i> (L.) Corrêa [BUBH2018068]	Rutaceae	bell	leaves	decoction	tree	Yes <sup>19-21</sup>
7.	<i>Terminalia bellirica</i> (Gaertn.) Roxb. [BUBH2018069]	Combretaceae	bhaora	fruit	raw	tree	Yes <sup>15,22</sup>
8.	<i>Paspalum fimbriatum</i> Kunth [BUBH2018070]	Poaceae	dapsa	whole plant	decoction	herb	No
9.	<i>Syzygium jambos</i> (L.) Alston [BUBH2018071]	Myrtaceae	godjaam	tender leaves	raw	tree	Yes <sup>23</sup>
10.	<i>Calotropis gigantea</i> (L.) R. Br. ex Schult. [BUBH2018072]	Apocynaceae	gogondo	leaves	decoction	shrub	Yes <sup>24,25</sup>
11.	<i>Rosa alba</i> L. [BUBH2018073]	Rosaceae	golabgufur	flower	infusion	shrub	No
12.	<i>Syzygium cumini</i> (L.) Skeels [BUBH2018074]	Myrtaceae	gwswm jamboo	seed	infusion	tree	Yes <sup>26-28</sup>
13.	<i>Hodgsonia heteroclita</i> (Roxb.) Hook.f. & Thomson [BUBH2018075]	Cucurbitaceae	hagrani jwgnar	fruit	decoction	climber	Yes <sup>29</sup>
14.	<i>Artocarpus heterophyllus</i> Lam. [BUBH2018076]	Moraceae	khanthal	leaves	infusion	tree	Yes <sup>30-32</sup>
15.	<i>Ficus racemosa</i> L. [BUBH2018077]	Moraceae	dumburu	fruit	decoction	tree	No
16.	<i>Alpinia galanga</i> (L.) Willd. [BUBH2018078]	Zingiberaceae	jermao	tuber	raw	herb	Yes <sup>33</sup>
17.	<i>Andrographis paniculata</i> (Burm.f.) Nees [BUBH2018009]	Acanthaceae	kalmith	leaves	decoction	herb	No
18.	<i>Oroxylum indicum</i> (L.) Kurz [BUBH2018012]	Bignoniaceae	Kharong khandai	leaves	decoction	tree	No

(Contd.)

Table 3 — Name of the plants, parts used, traditional formulation and habit of plants (*Contd.*)

Sl. No.	Scientific Name & Voucher Number	Family	Local Name (Bodo)	Parts Used	Preparation	Habit	References
19.	<i>Rauvolfia tetraphylla</i> L. [BUBH2018013]	Apocynaceae	kharwkha	root	decoction	shrub	No
20.	<i>Syzygium aromaticum</i> (L.) Merr. & L.M.Perry [BUBH20180079]	Myrtaceae	long	flower bud	decoction	tree	Yes <sup>34-36</sup>
21.	<i>Centella asiatica</i> (L.) Urb. [BUBH2018020]	Apiaceae	manimuni gidir	leaf	decoction	herb	Yes <sup>37-39</sup>
22.	<i>Hydrocotyle sibthorpioides</i> Lam. [BUBH2018019]	Apiaceae	manimuni fisa	whole plant	decoction	herb	No
23.	<i>Trigonella foenum-graecum</i> L. [BUBH2018080]	Fabaceae	methi	seed	infusion	herb	Yes <sup>40-42</sup>
24.	<i>Clerodendrum infortunatum</i> L. [BUBH2018047]	Lamiaceae	mwkhwna	tender leaf	decoction	shrub	No
25.	<i>Lindernia crustacea</i> (L.) F. Muell. [BUBH2018048]	Linderniaceae	na bikhi	whole plant	decoction	herb	No
26.	<i>Azadirachta indica</i> A. Juss. [BUBH2018051]	Meliaceae	neem	leaf	raw	tree	Yes <sup>43-45</sup>
27.	<i>Asparagus racemosus</i> Willd. [BUBH2018063]	Asparagaceae	nilikhor	roots	decoction	climber	Yes <sup>46,47</sup>
28.	<i>Catharanthus roseus</i> var. <i>albus</i> G. Don [BUBH2018081]	Apocynaceae	parboti	flower, leaves	decoction	herb	Yes <sup>48</sup>
29.	<i>Bryophyllum pinnatum</i> (Lam.) Oken [BUBH2018057]	Crassulaceae	path gaja	leaf	infusion	herb	Yes <sup>49</sup>
30.	<i>Ficus religiosa</i> L. [BUBH2018082]	Moraceae	phakhri	leaves	decoction	tree	Yes <sup>50-52</sup>
31.	<i>Nelumbo nucifera</i> Gaertn. [BUBH2018083]	Nelumbonaceae	podophul	stem	infusion	herb	Yes <sup>53,54</sup>
32.	<i>Terminalia chebula</i> Retz. [BUBH2018062]	Combretaceae	selekha	fruit	raw	tree	Yes <sup>55-57</sup>
33.	<i>Nyctanthes arbor-tristis</i> L. [BUBH2018084]	Oleaceae	sewali	flower	decoction	tree	Yes <sup>58</sup>
34.	<i>Piper longum</i> L. [BUBH2018085]	Piperaceae	simfri	fruit	raw	climber	Yes <sup>59</sup>
35.	<i>Alstonia scholaris</i> (L.) R. Br. [BUBH2018040]	Apocynaceae	sithona	bark	infusion	tree	No
36.	<i>Ocimum tenuiflorum</i> L. [BUBH2018045]	Lamiaceae	tulsi	roots	decoction	herb	No
37.	<i>Momordica charantia</i> L. [BUBH2018086]	Cucurbitaceae	udasi	tender leaf, fruit	decoction	climber	Yes <sup>60-62</sup>

some are wild, and some plants had been grown by them for easy availability as well as to conserve the valuable medicinal plants. Furthermore, on being asked about the plant availability, they also added that most of the plants which were available several years ago are now found to be decreased in their numbers. This shows the decrease of valuable medicinal plants.

The most cited plant families was seen to be Apocynaceae (16.6%), followed by Moraceae, Combretaceae and Myrtaceae (12.5%), Cucurbitaceae, Acanthaceae, Apiaceae and Lamiaceae (8.3%). The

most highly cited plant life forms are found to be a big tree (40.54%) followed by herbs (29.72%), shrubs (16.21%) and climbers (13.51%). *H. heteroclita* was found to be the most popular plant with 6 numbers of citations followed by *A. paniculata* (5 citations) and *R. tetraphylla* (3 citations). Out of the 37 reported plant species, 26 numbers of plant species have been mentioned once by the informers (Fig. 2). The most common plant part used in the preparation of traditional medicine was found to be leaves (51.35%), followed by fruit (16.21%), flowers (13.50%), roots

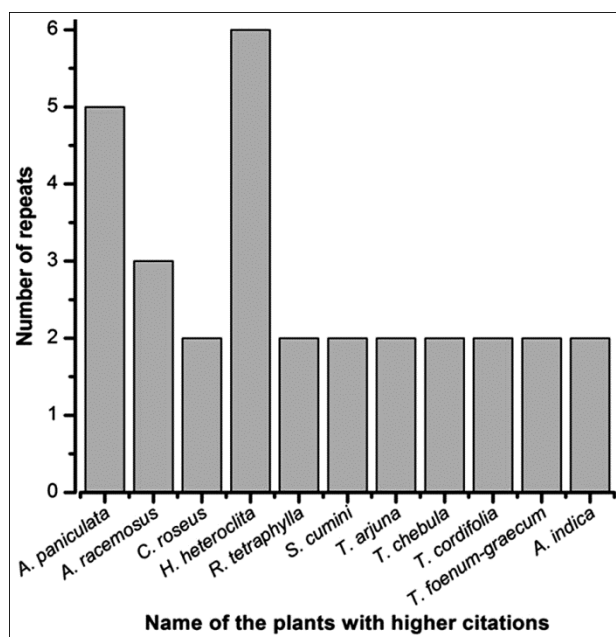


Fig. 2 — List of plants and citations by traditional healers

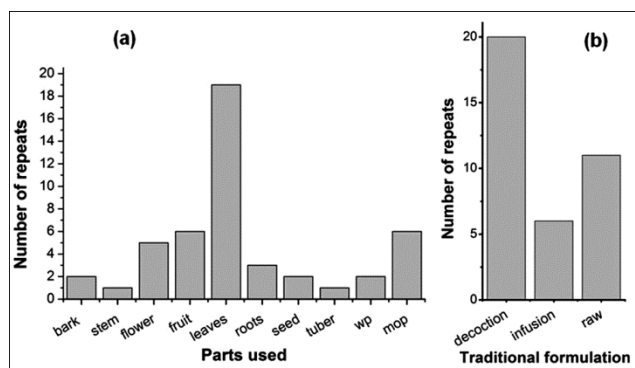


Fig. 3 a) — frequency of plant parts used during preparation of herbal medicines and b) traditional formulations adopted by the traditional healers in the preparation of herbal remedies. mop-more than one part, wp-whole plant

(8.10%), bark (5.40%), seed (5.40%), stem (2.70%) and tuber (2.70%) (Fig. 3a). In two plants, namely *H. sibthorpioides*, and *L. crustacea*, the whole plant was found to be used. Similar to our finding, leaves has been found to be the mostly used parts for preparation of herbal remedies in many other studies<sup>65,66</sup>. It has come into our observation that out of 37 plant species, in 6% of the plants more than one part is used for the preparation of traditional medicine. *Nelumbo nucifera* is the most common plant where leaves, rhizome and stem are used.

Decoction, infusion and raw preparations were found to be the common traditional herbal formulation practices among the traditional healers of Kokrajhar

district of Assam. Based on the method of preparation, our survey found that decoction (54.05%) is the mostly used method adopted by the traditional healers. Similar to our study, many ethnomedicinal survey reports also reported decoction being the mostly used method for preparation of herbal medicines<sup>67</sup>. Fig. 3b showed the various ethnomedicine preparations practiced by traditional healers. We have also performed a literature survey for all the plants cited by the traditional healers and found that 62.16% of the plants have one or more literature regarding antidiabetic property. However, 37.83% of the plants and the parts cited by the traditional healers were found to have no scientific literature on antidiabetic property. Similar to our study, an ethnobotanical survey was carried out in Nalbari district of Assam which revealed 35 species of plants belonging to 28 families which are used to cure diabetes and most of them are consumed in the form of raw juice<sup>68</sup>. In another study, Tarak *et al.*<sup>69</sup> surveyed and collected the ethnomedicinal information on antidiabetic medicinal plants of Dhemaji district showing the use of 21 plant species belonging to 20 families to cure diabetes. The traditional healers of Unakoti district of Tripura were also found to use 39 medicinal plant species belonging to 37 genera and 28 families for diabetes treatment<sup>70</sup>.

## Conclusion

The medicinal plant plays an important role in the treatment of Diabetes among the Bodo community of Kokrajhar district, Assam. Out of total 37 reported plants, 13 plants were found to have no scientific literature regarding the antidiabetic activity. *Andrographis paniculata* and *Rauvolfia tetraphylla*, although popularly used for diabetes cure in Kokrajhar district, there is no report of any experimental validation from India in favor of their antidiabetic activity. However, few literatures are available from outside of India. Most of the plants cited the traditional healers possesses scientific validation about antidiabetic property and therefore, the importance and significance of ethnomedicinal knowledge practiced since time immemorial cannot be ruled out. Traditional healers although do not have any scientific experimental methodology, but they do have some kind of experimentation by which diseases are cured. With the increase in urbanisation and mass deforestation, there is a rapid loss of many important medicinal plants. In addition to it, the blooming modern healthcare facilities have overshadowed the ethnomedicinal practice leading to the deterioration of

traditional knowledge. The present study will be helpful, to protect the ancient and traditional ethnomedicinal knowledge of Bodo community and also to preserve and transfer the knowledge to the next generations for the development of effective herbal remedies in the near future.

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### Reference

- Mamun-Rashid ANM, Hossain MS, Hassan N, Dash BK, Sapon MA *et al*, A review on medicinal plants with antidiabetic activity, *J Pharmacogn Phytochem*, 3 (4) (2014) 149-159.
- Hussain I, Khattak MUR, Muhammad RZ, Khan N, Khan FA *et al*, Phytochemicals screening and antimicrobial activities of selected medicinal plants of Khyberpakhtunkhwa Pakistan, *Afr J Pharm Pharmacol*, 5 (6) (2011) 746-750.
- Arumugam G, Manjula P & Paari N, A review: Anti diabetic medicinal plants used for diabetes mellitus, *J Acute Dis*, 2 (3) (2013) 196-200.
- Mahmud S, Shareef H, Ahmad M, Gouhar S & Rizwani GH, Pharmacognostic studies on fresh mature leaves of *Holoptelea integrifolia* (Roxb) planch, *Pak J Bot*, 42 (6) (2010) 3705-3708.
- Shankar R & Rawat MS, Conservation and cultivation of threatened and high valued medicinal plants in North East India, *Int J Biodivers. Conserv*, 5 (9) (2013) 584-591.
- Ahmed ZB, Yousfi M, Viaene J, Dejaegher B, Demeyer K *et al*, Potentially antidiabetic and antihypertensive compounds identified from *Pistacia atlantica* leaf extracts by LC fingerprinting, *J Pharm Biomed Anal*, 149 (2017) 547-556.
- WHO, Global Report on Diabetes- World Health Organization, (2016).
- Maryam R, A Review: Anti Diabetic medicinal plants used for diabetes mellitus. *Bulletin of Environment, Pharmacology and Life Sciences*, 4 (2) (2015) 163-180.
- Akah PA, Uzodinma SU & Okolo CE, Antidiabetic activity of aqueous and methanol extract and fractions of *Gongronema latifolium* (Asclepidaceae) leaves in Alloxan Diabetic Rats, *J Appl Pharm Sci*, 1 (2011) 99-102.
- Chikezie PC, Okey A, Ojiako & Nwufu KC, Overview of Anti-Diabetic Medicinal Plants: The Nigerian Research Experience, *Int J Diabetes Metab*, 6 (2015) 1-7.
- BTC Accord, 2003. [http://cdpsindia.org/btc\\_accord.asp](http://cdpsindia.org/btc_accord.asp).
- Sangetha MK, Mohana Priya CD & Vasanthi HR, Anti-diabetic property of *Tinospora cordifolia* and its active compound is mediated through the expression of Glut-4 in L6 myotubes, *Phytomedicine*, 20 (3-4) (2013) 246-248.
- Rajalakshmi M & Anita R,  $\beta$ -cell regenerative efficacy of a polysaccharide isolated from methanolic extract of *Tinospora cordifolia* stem on streptozotocin -induced diabetic Wistar rats, *Chem Biol Interact*, 243 (2016) 45-53.
- Nadig PD, Revankar RR, Dethe SM, Narayanswamy SB & Aliyar MA, Effect of *Tinospora cordifolia* on experimental diabetic neuropathy, *Indian J Pharmacol*, 44 (2012) 580-583.
- Nampoothiri SV, Prathapan A, Cherian OL, Raghu KG, Venugopalan VV *et al*, In vitro antioxidant and inhibitory potential of *Terminalia bellerica* and *Emblica officinalis* fruits against LDL oxidation and key enzymes linked to type 2 diabetes, *Food Chem Toxicol*, 49 (1) (2011) 125-131.
- D'souza JJ, D'souza PP, Fazal F, Kumar A, Bhat HP *et al*, Anti-diabetic effects of the Indian indigenous fruit *Emblica officinalis* Gaertn: active constituents and modes of action, *Food Funct*, 5 (4) (2014) 635-644.
- Biswas M, Kar B, Bhattacharya S, Kumar RBS, Ghosh AK *et al*, Antihyperglycemic activity and antioxidant role of *Terminalia arjuna* leaf in streptozotocin-induced diabetic rats, *Pharm Biol*, 49 (4) (2011) 335-340.
- Khaliq F, Parveen A, Singh S, Hussain ME & Fahim M, *Terminalia arjuna* Improves cardiovascular autonomic neuropathy in streptozotocin-induced diabetic rats, *Cardiovasc Toxicol*, 13 (1) (2013) 68-76.
- Mudi SR, Akhter M, Biswas SK, Muttalib MA, Choudhury S *et al*, Effect of aqueous extract of *Aegle marmelos* fruit and leaf on glycemic, insulinemic and lipidemic status of type-2 diabetic model rats, *J Complement Integr Med*, 14 (2) (2017). DOI: <https://doi.org/10.1515/jcim-2016-0111>
- Ansari P, Afroz N, Jalil S, Azad SB, Mustakim MG *et al*, Anti-hyperglycemic activity of *Aegle marmelos* (L.) corr. is partly mediated by increased insulin secretion,  $\alpha$ -amylase inhibition, and retardation of glucose absorption, *J Pediatr Endocrinol Metab*, 30 (1) (2017) 37-47.
- Panaskar SN, Joglekar MM, Taklikar SS, Haldavnekar VS & Arvindekar AU, *Aegle marmelos* Correa leaf extract prevents secondary complications in streptozotocin-induced diabetic rats and demonstration of limonene as a potent antiglycating agent, *J Pharm Pharmacol*, 65 (6) (2013) 884-894.
- Latha RC & Daisy P, Therapeutic potential of octylgallate isolated from fruits of *Terminalia bellerica* in streptozotocin-induced diabetic rats, *Pharm Biol*, 51 (6) (2013) 798-805.
- Gavillán-Suárez J, Aguilar-Perez A, Rivera-Ortiz N, Rodríguez-Tirado K, Figueroa-Cuilan W *et al*, Chemical profile and in vivo hypoglycemic effects of *Syzygium jambos*, *Costus speciosus* and *Tapeinochilos ananassae* plant extracts used as diabetes adjuvants in Puerto Rico, *BMC Complement Altern Med*, 15 (2015) 244.
- Rathod NR, Chitme HR, Irchhaiya R & Chandra R, Hypoglycemic Effect of *Calotropis gigantea* Linn. Leaves and Flowers in Streptozotocin-Induced Diabetic Rats, *Oman Med J*, 26 (2) (2011) 104-108.

- 25 Choudhary NK, Sharma S, Jha AK, Karchuli MS & Dwivedi J, Antioxidant potential and protection of pancreatic  $\beta$ -cells by *Calotropis gigantea* in streptozocin induced diabetic rats, *J Complement Integr Med*, 9 (2012).
- 26 Baldissera G, Sperotto ND, Rosa HT, Henn JG, Peres VF *et al*, Effects of crude hydro alcoholic extract of *Syzygium cumini* (L.) Skeels leaves and continuous aerobic training in rats with diabetes induced by a high-fat diet and low doses of streptozotocin, *J Ethnopharmacol*, 194 (2016) 1012-1021.
- 27 Yousaf S, Hussain A, Rehman S, Aslam MS & Abbas Z, Hypoglycemic and hypolipidemic effects of *Lactobacillus fermentum*, fruit extracts of *Syzygium cumini* and *Momordica charantia* on diabetes induced mice, *Pak J Pharm Sci*, 29 (5) (2016) 1535-1540.
- 28 Raffaelli F, Borroni F, Alidori A, Tirabassi G, Faloia E *et al*, Effects of in-vitro supplementation with *Syzygium cumini* (L.) on platelets from subjects affected by diabetes mellitus, *Platelets*, 26 (8) (2015) 720-725.
- 29 Usha T, Goyal AK, Narzary D, Prakash L, Wadhwa G *et al*, Identification of bioactive glucose-lowering compounds of methanolic extract of *Hodgsonia heteroclita* fruit pulp, *Front Biosci*, 23 (2018) 875-888.
- 30 Ajiboye BO, Adeleke Ojo O, Adeyonu O, Imiere O, Emmanuel Oyinloye B *et al*, Ameliorative Activity of ethanolic extract of *Artocarpus heterophyllus* stem bark on alloxan-induced diabetic rats, *Adv Pharm Bull*, 8 (1) (2018) 141-147.
- 31 Chackrewarthy S, Thabrew MI, Weerasuriya MK & Jayasekera S, Evaluation of the hypoglycemic and hypolipidemic effects of an ethylacetate fraction of *Artocarpus heterophyllus* (Jak) leaves in streptozotocin-induced diabetic rats, *Pharmacogn Mag*, 6 (23) (2010) 186-190.
- 32 Ajiboye BO, Ojo OA, Adeyonu O, Imiere OD, Fadaka AO *et al*, Ameliorative activity of ethanol extract of *Artocarpus heterophyllus* stem bark on pancreatic  $\beta$ -cell dysfunction in alloxan-induced diabetic rats, *J Evid Based Complementary Altern Med*, 22 (4) (2017) 538-543.
- 33 Kaushik P, Kaushik D, Yadav J & Pahwa P, Protective effect of *Alpinia galanga* in STZ induced diabetic nephropathy, *Pak J Biol Sci*, 16 (16) (2013) 804-811.
- 34 Adefegha SA, Oboh G, Adefegha OM, Boligon AA & Athayde ML, Antihyperglycemic, hypolipidemic, hepatoprotective and antioxidative effects of dietary clove (*Syzygium aromaticum*) bud powder in a high-fat diet/streptozotocin-induced diabetes rat model, *J Sci Food Agric*, 94 (13) (2014) 2726-2737.
- 35 Khathi A, Serumula MR, Myburg RB, Van Heerden FR & Musabayane CT, Effects of *Syzygium aromaticum*-derived triterpenes on postprandial blood glucose in streptozotocin induced diabetic rats following carbohydrate challenge, *PLoS One*, 8 (11) (2013) 1-8.
- 36 Kuroda M, Mimaki Y, Ohtomo T, Yamada J, Nishiyama T *et al*, Hypoglycemic effects of clove (*Syzygium aromaticum* flower buds) on genetically diabetic KK-Ay mice and identification of the active ingredients, *J Nat Med*, 66 (2) (2012) 394-399.
- 37 Kabir AU, Samad MB, D'Costa NM, Akhter F, Ahmed A *et al*, Anti-hyperglycemic activity of *Centella asiatica* is partly mediated by carbohydrase inhibition and glucose-fiber binding, *BMC Complement Altern Med*, (2014) 1-14.
- 38 Maulidiani, AF, Khatib A, Perumal V, Suppaiah V, Ismail A *et al*, Metabolic alteration in obese diabetes rats upon treatment with *Centella asiatica* extract, *J Ethnopharmacol*, 180 (2016) 60-69.
- 39 Masola B, Oguntibeju OO & Oyenihni AB, *Centella asiatica* ameliorates diabetes-induced stress in rat tissues via influences on antioxidants and inflammatory cytokines, *Biomed Pharmacother*, 101 (2018) 447-457.
- 40 Sankar P, Subhashree S, & Sudharani S, Effect of *Trigonella foenum-graecum* seed powder on the antioxidant levels of high fat diet and low dose streptozotocin induced type II diabetic rats, *Eur Rev Med Pharmacol Sci*, 3 (2012) 10-17.
- 41 Pradeep SR & Srinivasan K, Alleviation of oxidative stress-mediated nephropathy by dietary fenugreek (*Trigonella foenum-graecum*) seeds and onion (*Allium cepa*) in streptozotocin-induced diabetic rats, *Food Funct*, 9 (1) (2018) 134-148.
- 42 Kumar P, Kale RK & Baquer NZ, Antihyperglycemic and protective effects of *Trigonella foenum-graecum* seed powder on biochemical alterations in alloxan diabetic rats, *Eur Rev Med Pharmacol Sci*, 3 (2012) 18-27.
- 43 Kazeem MI, Dansu TV & Adeola SA, Inhibitory effect of *Azadirachta indica* A. Juss leaf extract on the activities of alpha-amylase and alpha-glucosidase, *Pak J Biol Sci*, 16 (21) (2013) 1358-1362.
- 44 Perez Gutierrez RM & de Jesus Martinez Ortiz M, Beneficial effect of *Azadirachta indica* on advanced glycation end-product in streptozotocin-diabetic rat, *Pharm Biol*, 52 (11) (2013) 1435-1444.
- 45 Gupta NK, Srivastva N, Bubber P & Puri S, The Antioxidant Potential of *Azadirachta indica* Ameliorates Cardioprotection Following Diabetic Mellitus-Induced Microangiopathy, *Pharmacogn Mag*, 12 (Suppl-2) (2016) 371-378.
- 46 Somania R, Singhai AK, Shivgunde P & Jain D, *Asparagus racemosus* Willd (Liliaceae) ameliorates early diabetic nephropathy in STZ induced diabetic rats, *Indian J Exp Biol*, 50 (7) (2012) 469-475.
- 47 Hannan JM, Marenah L, Ali L, Rokeya B, Flatt PR *et al*, Insulin secretory actions of extracts of *Asparagus racemosus* root in perfused pancreas, isolated islets and clonal pancreatic beta-cells, *J Endocrinol*, 192 (1) (2007) 159-168.
- 48 Khan A, A comparative study of antidiabetic activity of *Catharanthus roseus* and *Catharanthus alba* flower extracts on alloxan induced diabetic rats, *World Int J Pharm Pharm Sci*, (2016).
- 49 Ojewole JA, Antinociceptive, anti-inflammatory and antidiabetic effects of *Bryophyllum pinnatum* (Crassulaceae) leaf aqueous extract, *J Ethnopharmacol*, 99 (1) (2005) 13-19.
- 50 Pandit R, Phadke A & Jagtap A, Antidiabetic effect of *Ficus religiosa* extract in streptozotocin-induced diabetic rats, *J Ethnopharmacol*, 128 (2) (2010) 462-466.
- 51 Kirana H, Agrawal SS & Srinivasan BP, Aqueous extract of *Ficus religiosa* linn. reduces oxidative stress in experimentally induced Type 2 diabetic rats, *Indian J Exp Biol*, 47 (10) (2009) 822-826.



- 52 Kirana H, Jali MV & Srinivasan BP, The study of aqueous extract of *Ficus religiosa* Linn. on cytokine TNF- $\alpha$  in type 2 diabetic rats, *Pharmacogn Res*, 3 (1) (2011) 30-34.
- 53 Kato E, Inagaki Y & Kawabata J, Higenamine 4'-O- $\beta$ -D-glucoside in the lotus plumule induces glucose uptake of L6 cells through  $\beta$ 2-adrenergic receptor, *Bioorg Med Chem*, 23 (13) (2015) 3317-3321.
- 54 Mukherjee PK, Saha K, Pal M & Saha BP, Effect of *Nelumbo nucifera* rhizome extract on blood sugar level in rats, *J Ethnopharmacol*, 58 (3) (1997) 207-213.
- 55 Huang YN, Zhao DD, Gao B, Zhong K, Zhu RX *et al*, Anti-hyperglycemic effect of chebulagic acid from the fruits of *Terminalia chebula* Retz, *Int J Mol Sci*, 13 (5) (2012) 6320-6333.
- 56 Kim JH, Hong CO, Koo YC, Kim SJ & Lee KW, Oral administration of ethyl acetate-soluble portion of *Terminalia chebula* conferring protection from streptozotocin-induced diabetic mellitus and its complications, *Biol Pharm Bull*, 34 (11) (2011) 1702-1709.
- 57 Kumar GPS, Arulselvan P & Kumar DS, Anti-diabetic activity of fruits of *Terminalia chebula* on streptozotocin induced diabetic rats, *J Health Sci*, 52 (3) (2006) 283-291.
- 58 Rangika BS, Dayananda PD & Peiris DC, Hypoglycemic and hypolipidemic activities of aqueous extract of flowers from *Nycantus arbor-tristis* L. in male mice, *BMC Complement Altern Med*, 15 (2015) 289.
- 59 Manoharan S, Silvan S, Vasudevan K & Balakrishnan S, Antihyperglycemic and antilipidperoxidative effects of *Piper longum* (Linn.) dried fruits in alloxan induced diabetic rats, *J Biol Sci*, 7 (1) (2007) 161-168.
- 60 Mahmoud MF, El Ashry FE, El Maraghy NN & Fahmy A, Studies on the antidiabetic activities of *Momordica charantia* fruit juice in streptozotocin-induced diabetic rats, *Pharm Biol*, 55 (1) (2017) 758-765.
- 61 Ma C, Yu H, Xiao Y & Wang H, *Momordica charantia* extracts ameliorate insulin resistance by regulating the expression of SOCS-3 and JNK in type 2 diabetes mellitus rats, *Pharm Biol*, 55 (1) (2017) 2170-2177.
- 62 Rudá-Kučerová J, Kotolová H & Koupy D, Effectiveness of phytotherapy in supportive treatment of Type 2 diabetes mellitus III. *Momordica (Momordica charantia)*, *Ceska Slov Farm*, 64 (4) (2015) 126-32.
- 63 Ahmad L, Semotiuk A, Zafar M, Ahmad M, Sultana S *et al*, Ethnopharmacological documentation of medicinal plants used for hypertension among the local communities of DIR Lower, Pakistan, *J Ethnopharmacol*, 175 (2015) 138-146.
- 64 Fayaz M, Jain AK, Bhat MH & Kumar A, Ethnobotanical survey of Daksum forest range of Anantnag District, Jammu and Kashmir, India, *J Herbs Spices Med Plants*, 25 (1) (2019) 1-13
- 65 Muthu C, Ayyanar M, Raja N & Ignacimuthu S, Medicinal plants used by traditional healers in Kancheepuram District of Tamil Nadu, India, *J Ethnobiol Ethnomed*, 2 (43) (2006).
- 66 Ashfaq S, Ahmad M, Zafar M, Sultana S, Bahadur S *et al*, Medicinal Plant Biodiversity used among the rural communities of Arid Regions of Northern Punjab, Pakistan, *Indian J Tradit Know*, 18 (2) (2019) 226-241.
- 67 Tshikalange TE, Mophuting BC, Mahore J, Winterboer S & Lall N, An ethnobotanical study of medicinal plants used in villages under Jongilanga tribal council, Mpumalanga, South Africa, *Afr J Tradit Complement Altern Med*, 13 (3) (2016) 83-89.
- 68 Chakravarty S & Kalita JC, An investigation on antidiabetic medicinal plants used by villagers in Nalbari district, Assam, India, *Int J Pharm Sci Res*, 3 (6) (2012) 1693-1697.
- 69 Tarak D, Namsa ND, Tangiang S, Arya SC, Rajbonshi B *et al*, An inventory of the ethnobotanicals used as anti-diabetic by a rural community of Dhemaji district of Assam, Northeast India, *J Ethnopharmacol*, 13 (2) (2011) 345-350.
- 70 Ghosh Tarafdar R, Nath S, Das Talukdar A & Dutta Choudhury M, Antidiabetic plants used among the ethnic communities of Unakoti district of Tripura, India, *J Ethnopharmacol*, 160 (2015) 219-226.