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Research Article

Traditional therapeutic practices of antidiabetic herbs in certain districts of Assam and their validation based on the Glycemic index (GI) evaluation of commonly used herbs

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Abstract
Traditional medicinal plants have been widely used for managing diabetes, especially in rural and indigenous communities. However, scientific validation of these practices remains limited. This study aims to document the ethnobotanical knowledge of plant-based approaches to diabetes management and to assess the Glycemic index (GI) of the most commonly used herbs to validate their potential efficacy. A structured survey was conducted across several districts to collect data on the traditional use of medicinal herbs for diabetes management. The most frequently reported plant species were chosen for further analysis. Their glycemic index was determined in a murine *in vivo* model to assess their impact on blood glucose levels. The survey revealed a strong reliance on plant-based remedies for diabetes management. Several plant species demonstrated significant potential to regulate glucose levels, as indicated by their glycemic index values, including *Dioscorea villosa, Setaria italica, Tinospora cordifolia, Neolamarckia cadamba, Alternanthera sessilis*, and *Moringa oleifera.* The findings suggest a scientific basis for the continued use of these herbs in traditional medicine. This study reinforces the importance of traditional knowledge in diabetes management and highlights the need for further pharmacological validation of these plant species. The results provide a foundation for developing plant-based interventions as complementary therapeutic options for diabetes care.

Keywords: Diabetes management, Ethnobotany, Glycemic index, Indigenous knowledge, Medicinal plants, Plant-based therapy, Traditional medicine

INTRODUCTION

Diabetes is one of the most widespread chronic diseases, affecting a significant portion of the global population. According to the World Health Organization (WHO), both the incidence and prevalence of diabetes have been steadily rising over the past decades (Harding *et al*., 2019). As of 2022, the International Diabetes Federation estimated that approximately 537 million people worldwide have diabetes, and if current trends continue, this number could surge to 784 million by 2045 (Sun *et al*., 2022). India, often referred to as the "Diabetes capital" of the world, faces a particularly high burden (Joshi and Parikh, 2007). Diabetes is an endocrine disorder characterized by persistent hyperglycemia. It is primarily classified into two main types: Diabetes mellitus and Diabetes insipidus (Sarkar *et al*., 2019). Diabetes mellitus results from an insulin deficiency, while iabetes insipidus is due to a deficiency in the hormone vasopressin (Bankir *et al*., 2001; Samarasinghe and Vokes, 2006). Among these, Diabetes mellitus is far more common. Within Diabetes mellitus, there are two subtypes: type 1 and type 2. Type 1 diabetes mellitus (T1DM), often referred to as autoimmune diabetes, is a long-term condition characterized by insulin deficiency due to destruction of pancreatic β-cells, leading to elevated blood sugar levels. While symptoms typically emerge in childhood or adolescence, they can occasionally appear later in life.
The exact cause of T1DM remains unclear, but it is

believed to develop due to T cell-mediated damage to β cells (Katsarou *et al*., 2017). In type 2 diabetes mellitus (T2DM), insulin production is reduced, and the body becomes resistant to insulin. T2DM is a growing global health issue, strongly associated with the rise in obesity rates. People with T2DM face a high risk of both microvascular complications, such as retinopathy, nephropathy, and neuropathy and macrovascular complications, including cardiovascular diseases due to hyperglycemia and components of the metabolic syndrome linked to insulin resistance. Both environmental factors such as obesity, poor diet, and lack of physical activity and genetic predispositions play roles in the complex disruptions that lead to impaired glucose regulation in T2DM. The primary issues are insulin resistance and reduced insulin secretion, but at least six additional pathophysiological factors contribute to the disruption of glucose metabolism in this condition (DeFronzo *et al*., 2015). When type 2 diabetes causes hyperglycemia during pregnancy, it is known as gestational diabetes, typically occurring in the second or third trimester. Gestational diabetes mellitus (GDM) is characterized as any carbohydrate intolerance first identified during pregnancy. It occurs in approximately 2–5% of normal pregnancies, with its prevalence influenced by the population's predisposition to type 2 diabetes mellitus. GDM is often associated with detrimental outcomes for the mother, foetus, newborn, child, and even the adult offspring of the diabetic mother (Ashwal and Hod, 2015).

Insulin is a peptide hormone produced by the beta cells of the islets of Langerhans in the pancreas. It plays a crucial role in facilitating the uptake of glucose from the bloodstream into cells, particularly in the liver, adipose tissue, and muscles (Rahman *et al*., 2021). Insulin regulates the metabolism of carbohydrates, proteins, and fats, ensuring energy availability in both fasting and fed states (Qaid and Abdelrahman, 2016). During fasting, insulin levels are low in the portal venous system, allowing minimal glucose production to meet the needs of glucose-dependent tissues, such as the peripheral nervous system (Lema-Pérez, 2021). Low insulin levels in the blood promote lipolysis in adipose tissue, releasing fatty acids and prompting the body to use lipids rather than glucose (Morigny *et al*., 2016). The liver stores about 80% of glucose during fasting, with glycogenolysis and gluconeogenesis promoted by counter-regulatory hormones such as glucagon (Kajani *et al*., 2024). In the fed state, insulin levels rise in the portal venous system, promoting glucose uptake by fat and skeletal muscle and facilitating energy storage through lipogenesis and glycogenesis. In the liver, insulin inhibits glucose production by suppressing glycogenolysis and gluconeogenesis. Overall, insulin release during the fed state aims to maintain normal serum glucose levels and promote energy storage for later use during fasting (Norton *et al*., 2022).

Diabetes mellitus is a clinical condition defined by hyperglycemia, resulting from either an absolute or relative insulin deficiency and insulin resistance. This deficiency, whether complete or partial, impacts the metabolism of carbohydrates, proteins, fats, water, and electrolytes (Balaji *et al*., 2019). In India, alternative medical systems such as Ayurveda, Siddha, and Unani are widely practised. In Ayurveda, diabetes is referred to as Madhumeha. Several herbal remedies, including decoctions (boiled extracts), Swaras (expressed juices), Asav-Arisht (fermented juices), and powders, are mentioned for treating Madhumeha. These treatments are primarily derived from plants (Das *et al*., 2011). While several effective Western medications are available for the treatment of T2DM, managing the disease with drugs that have fewer side effects and are more affordable remains a significant challenge (Nyenwe *et al*., 2011). Common side effects of these medications include weight gain, bone loss, and an increased risk of cardiovascular events, which may become more pronounced with prolonged use (Meier *et al*., 2016; Low Wang *et al*., 2016). Additionally, the chronic nature of T2DM necessitates long-term medication, making treatment costly. Herbal remedies offer a promising alternative, either as a replacement or as a supplement to conventional Western treatments.

Herbal treatments for Type 2 diabetes mellitus (T2DM) can address various mechanisms such as improving insulin sensitivity, stimulating insulin production, or decreasing carbohydrate absorption (Li *et al*., 2004). In contrast to Western pharmaceuticals, which typically feature a single active compound targeting a specific action, herbal formulations often contain multiple active ingredients that affect several mechanisms. Herbal medicine follows a holistic approach, focusing on the interconnectedness of the body. While Western medications are generally more effective at reducing blood glucose levels, herbal supplements have shown potential for managing diabetic complications (Ceylan-Isik *et al*., 2008). Therefore, herbal medicine may serve as an adjunct or complement to conventional treatments, potentially enhancing therapeutic outcomes.

Traditional medicine has been a cornerstone in the treatment and prevention of various ailments in both Chinese and Indian cultures. Around 800 plant species have been recognized for their role in managing or preventing type 2 diabetes mellitus (T2DM). These plants are often used in either single herbal extracts or more complex formulations. More than 400 of these extracts have demonstrated efficacy in both *in vitro* and *in vivo* studies (Prabhakar and Doble, 2011). The pharmacological actions of these herbs can be categorized into several mechanisms, including: (1) reducing carbohydrate absorption, (2) enhancing insulin sensitivity, (3) boosting glucose uptake in peripheral tissues, (4) stimulating insulin secretion, (5) enhancing the activity of endogenous incretins, (6) providing antioxidant benefits and reducing cell apoptosis, and (7) promoting glycogenesis or inhibiting hepatic glycogenolysis (Bhat *et al*., 2011; Prabhakar and Doble, 2011).

In this context, the current survey was conducted to provide a comprehensive overview of traditional methods of diabetes management across several districts of Assam. The study aimed to qualitatively identify traditional medicinal herbs known and accessible to people with diabetes in Assam and to calculate the Glycemic index (GI) of the six most commonly used herbs.

MATERIALS AND METHODS

Ethnobotanical survey

The study was conducted in both urban and rural areas across ten districts of Assam, including Kamrup, Nalbari, Sivasagar, Lakhimpur, Goalpara, Dhubri, Nagaon, Jorhat, Baksa, and Karbi Anglong. The urban part was conducted in the Kamrup (Metro) district of Assam, which has an area of approximately 955 square kilometres. This district includes the city of Guwahati, which is the largest urban area in Assam. The field survey was conducted using a purposive or selective sampling method, with a standard, structured bilingual questionnaire (Assamese and English), through in-person interviews, telephone conversations, and Google Forms. A total of 437 people participated in the study over 12 months, from August 2023 to August 2024. Altogether, 150 personal interviews, 100 over-the-phone conversations and 187 Google forms were recorded. Local healers were also included in the data collection, as villagers often rely on them to treat health ailments. Participants provided informed consent for the publication of this report. The questionnaire (Supplementary S1) was designed to collect data on the informants' age, sex, family history of diabetes, general knowledge about diabetes (including diagnosis), access to allopathic medicine, dietary habits, and traditional medicinal plants used for diabetes management. The survey did not include plant formulations. The medicinal plants mentioned by the participants were documented in the study using their local names. A literature search was then conducted across various platforms, including Google Scholar, PubMed, Web of Science, Scopus, OSADHI, and NEI-MPDB, to gather data on their diverse biological activities, which have been scientifically validated or supported by evidence.

Collection of plant materials and preparation of extracts

From the survey data, six most commonly used herbs viz., *Dioscorea villosa, Setaria italica, Tinospora cordifolia, Neolamarckia cadamba, Alternanthera sessilis* and *Moringa oleifera* were collected from different locations of Assam during April-October, 2024 and identified at Botany Departments of Gauhati University and Osmania University vide accession numbers: OUAS-263, OUAS-262, GUBH20711, GUBH20713, GUBH19998 and GUBH20712, respectively,

The leaves of *N. cadamba, A.ternanthera sessilis, M. oleifera,* tuber of *D. villosa*, grains of *S. italica*, and stem of *T. cordifolia,* were washed and dried for 7-10 days in a shaded environment (23-27°±2°C). The shade dried samples were powdered in an electric stainless grinder machine. The powdered material was extracted using double-distilled water, ethanol, and methanol through the Soxhlet method at room temperature (Tiwari *et al*., 2011). The resulting extracts were concentrated to dryness using a rotary evaporator and subsequently utilized for phytochemical screening.

Qualitative phytochemical screening

To determine the presence of bioactive components in the aqueous, methanolic, and ethanolic extracts of the selected herbs, phytochemical screening tests were conducted according to the standard procedures of Trease and Evans (1989), Sofowara (1993), and Harborne (1998).

Gas chromatography-mass spectrometry (GCMS) analysis of methanolic extracts

A 10 mg sample was weighed and mixed with 1 ml of methanol, followed by vortexing for 10 minutes. The mixture was sonicated for 60 minutes and centrifuged at 10,000 rpm for 10 minutes at 4 °C. The supernatants were collected and vacuum-concentrated to dryness. The dried extracts were derivatized to enhance the detection of polar phytometabolites for GC-MS analysis. First, 90 µL of o-methylhydroxylamine hydrochloride in pyridine was added to the dried sample and incubated at 60 °C for 90 minutes in a water bath. The reaction mixture was then silylated using 200 µL of MSTFA (N-Methyl-N-(trimethylsilyl)trifluoroacetamide) with 1% TMCS (Trimethylchlorosilane) as a catalyst at 60 °C for 120 minutes in a dry bath. The derivatized mixture was vacuum-concentrated for 90 minutes, reconstituted with 300 µL of n-hexane, and vortexed. A 1 µL aliquot of the prepared sample was injected into the GC-MS system (Intuvo 9000 GC and 5977B MSD, Agilent Technologies, Palo Alto, CA, USA) for analysis.

Experimental animals

Ten adult male Wistar rats (10–12 weeks old, body wt. 75–95g) were used in this study. They were procured from College of Veterinary Science, Assam Agricultural University, Khanapara. Before the experiment, the rats were acclimatized for seven days in ventilated polypropylene cages lined with husk bedding, which was replaced weekly. The animals were maintained under standardized conditions: a controlled temperature of 25±2°C, a 12-hour light-dark cycle, and 52±5% relative humidity. They were provided with a standard rodent pellet diet and water ad libitum, and were monitored regularly.

Animal ethical approval

The experiment was conducted in the Department of Zoology, Cotton University, with animal ethical committee clearance obtained from the Institutional Animal Ethics Committee (Approval No. 16/IAEC/CU/27/11/2024), and all experiments were conducted in compliance with CPCSEA guidelines.

Oral glucose tolerance test (OGTT) and calculation of Glycemic index (GI)

The GI is a numerical scale used to assess how much a carbohydrate-rich food raises blood sugar levels relative to a reference food, usually glucose or white bread. Foods are rated from 0 to 100, with higher scores indicating a stronger effect on blood glucose levels. The most commonly used plants identified from the survey for traditional diabetes management were collected, and their Glycemic index was determined using both experimental and mathematical methods, following the Australian Standard (2007) protocol.

For determination of GI, OGTT was performed. Ten experimental animals were used for the study. The reference food taken was glucose or white bread, with a GI of 100. The test food is the plant extract sample, the GI of which is to be tested. After an overnight fast, baseline blood glucose levels (0 min) of all the rats, are measured by collecting a small blood sample from the tail vein and analyzing it using a Accu-Check blood glucose meter. Immediately after baseline measurement, each rat received an oral glucose load (2 g/kg body weight) administered via oral gavage, and blood samples were collected at intervals (e.g., every 15-30 minutes) over two hours. The same procedure was repeated on different days with the test plant extracts (100 mg/kg body weight). Blood glucose levels were measured via tail pricks using a Accu-Check blood glucose meter and plotted to create glucose response curves (Table 4). The incremental area under the curve (iAUC) for both the reference and test plant extracts was calculated (Wolever *et al*., 1991).

The GI was then determined using the formula:

$$GI = \left(\frac{iAUC\ of\ Test\ Food}{iAUC\ of\ Reference\ Food}\right) \times 100$$

where, iAUC of Test Food = incremental area under the glucose response curve after consumption of plant extract; iAUC of Reference Food = incremental area under the glucose response curve after glucose administration.

Statistical analysis

Data of blood glucose levels were expressed as mean ± SE (n=10). Comparisons among groups were made by two-way ANOVA. The values with $p \leq 0.05$ were considered statistically significant. The graphs have been made using Excel version 16 and GraphPad Prism version 10.2.2.

RESULTS

Survey study

Response and gender demographic

From the survey conducted across various districts, a total of 437 responses were recorded (Table 1), with representation from both male and female participants. Kamrup district had the highest number of responses (108), with a male-to-female ratio of 68:40. Other districts such as Sivsagar (91 responses) and Nalbari (86 responses) also showed notable participation, with a balanced gender distribution in Sivsagar (42 males and 49 females) and a higher number of males in Nalbari (62 males and 24 females). Districts such as Dhubri, Nagaon, Jorhat, and Karbi Anglong reported lower responses, ranging between 8 and 16, but still demonstrated gender diversity.

Distribution of diabetes among the people studied

In terms of the glucose levels, Kamrup exhibited a significant number of diabetic individuals (85), with 23 classified as pre-diabetic, followed by Sivsagar, with 76

Table 1. Number of responses and gender distribution of people participating in the survey

District	Number of responses	Gender (Male/Female)
Kamrup	108	68/40
Sivsagar	91	42/49
Nalbari	86	62/24
Lakhimpur	67	35/32
Goalpara	23	13/10
Dhubri	15	8/7
Nagaon	10	5/5
Jorhat	16	9/7
Baksa	13	5/8
Karbi Anglong	8	3/5

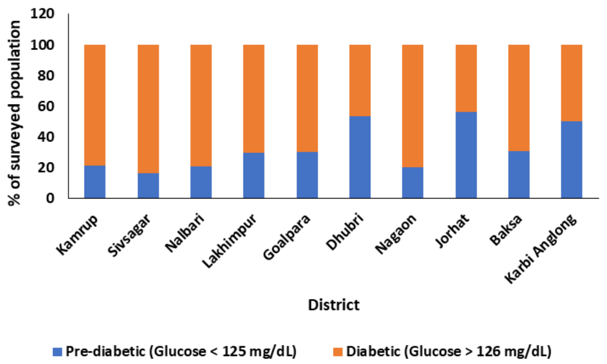


Fig. 1. *Percentage of people representing the prevalence of diabetes type in the surveyed population*

diabetic and 15 pre-diabetic respondents. Similar trends were observed in Nalbari and Lakhimpur, where the diabetic group was notably higher than the pre-diabetic group, indicating a higher diabetic prevalence (Fig. 1). In contrast, districts like Dhubri, Nagaon, Jorhat, Baksa, and Karbi Anglong reported fewer cases of both diabetic and pre-diabetic conditions, ranging from 2 to 9 per category, suggesting a relatively lower prevalence of diabetes in these regions.

Medicinal plants used by the people

From the survey, it was observed that 32 plants were used by the studied Individuals as part of their eating habits or as a means of T2DM management. The plants noted were *Acorus calamus*, *Adhatoda vasica*, *Aegle marmelos*, *Allium cepa*, *Allium sativum*, *A. sessilis, Aloe barbadensis*, *Annona squamosa*, *Asparagus racemosus*, *Azadirachta indica*, *Beta vulgaris*, *Carica papaya*, *Centella asiatica*, *Curcuma longa*, *Emblica officinalis*, *Gymnema sylvestre*, *Ipomoea batatas*, *Mangifera indica*, *Momordica charantia*, *M. oleifera*, *Murraya koenigii*, *N.cadamba, Nigella sativa*, *Ocimum sanctum*, *Pterocarpus marsupium*, *Setaria italica, Syzygium cumini*, *Terminalia chebula*, *T.cordifolia*, *Trigonella foenum-graecum*, *Vachellia nilotica*, and *Dioscorea* sp. The common name, family, plant part used, ethnomedicinal usage, tribe/community, % utilized by people studied is summarised in Table 2.

The pharmaceutical drugs which are generally recommended for diabetes management and are used by the studied Individuals is also summarised in Table 3 along with their mechanism of action, common use, side effects, typical dosages and examples.

Qualitative phytochemical screening

The results of the phytochemical screening of the selected commonly used herbs viz., *D. villosa, S. italica, T.cordifolia, N.cadamba, A. sessilis* and *M. oleifera* showed that most all the phytochemicals, viz. alkaloids, phenols, tannins, flavonoids, glycosides, terpenoids, and saponins are present at different levels of concentration, with higher levels observed in the methanolic extracts (Fig. 2,3).

Gas chromatography-mass spectrometry (GC-MS) analysis

GC–MS analysis of the methanolic extracts of the selected plants revealed a diverse profile of bioactive marker compounds, representing different classes such as organic acids, fatty acids, sterols, phenolic derivatives, and secondary metabolites. The principal compounds identified, along with their retention times and known biological activities, are summarised in Table 4 and Fig. 4.

The methanolic extract of *D. villosa* showed the presence of benzoic acid, malic acid, lauric acid, shikimic acid, protocatechuic acid, quinic acid, myo-inositol, linoleic acid, and 1-monopalmitin. The identified compounds are reported to possess antioxidant, anti-inflammatory, antimicrobial, and metabolic regulatory properties.

The extract of *S. italica* was characterized by the occurrence of 2,4-di-tert-butylphenol, lauric acid, myo-inositol, linoleic acid, and stigmasterol. These metabolites are linked with cardioprotective, neuroprotective, anti-inflammatory, and immunomodulatory activities.

The methanolic extract of *T. cordifolia* contained glycolic acid, propanoic acid, benzoic acid, itaconic acid, malic acid, citric acid, linoleic acid, oleic acid, and stearic acid. These metabolites contribute to energy metabolism and lipid regulation and exhibit broad antimicrobial, antioxidant, and anti-inflammatory functions.

The *N. cadamba* extract revealed the presence of benzoic acid, salicylic acid, decanoic acid, malic acid, 2,4-di-tert-butylphenol, protocatechuic acid, quinic acid, caffeic acid, and α-linolenic acid. These phytoconstituents are associated with antidiabetic, anticancer, antioxidant, and antimicrobial properties.

The extract of *A. sessilis* was rich in sterols and fatty acids, including 2,4-di-tert-butylphenol, stearic acid, α-linolenic acid, stigmasterol, and β-sitosterol. These bioactives are known for their cardioprotective, anti-inflammatory, antioxidant, and anticancer roles.

The methanolic extract of *M. oleifera* showed the occurrence of limonene, 2,4-di-tert-butylphenol, stearic acid, α-linolenic acid, 1-monopalmitin, β-sitosterol, and glycerol monostearate. The identified metabolites are associated with antimicrobial, antioxidant, cardioprotective, and immunomodulatory effects.

Blood glucose response curves

The oral glucose tolerance test (OGTT) was performed in rats to compare the postprandial glycemic response of glucose (reference food) with that of the selected plant extracts. Administration of glucose caused a sharp elevation in blood glucose levels, reaching a peak at 45 min (191.09 ± 0.08 mg/dl) before gradually

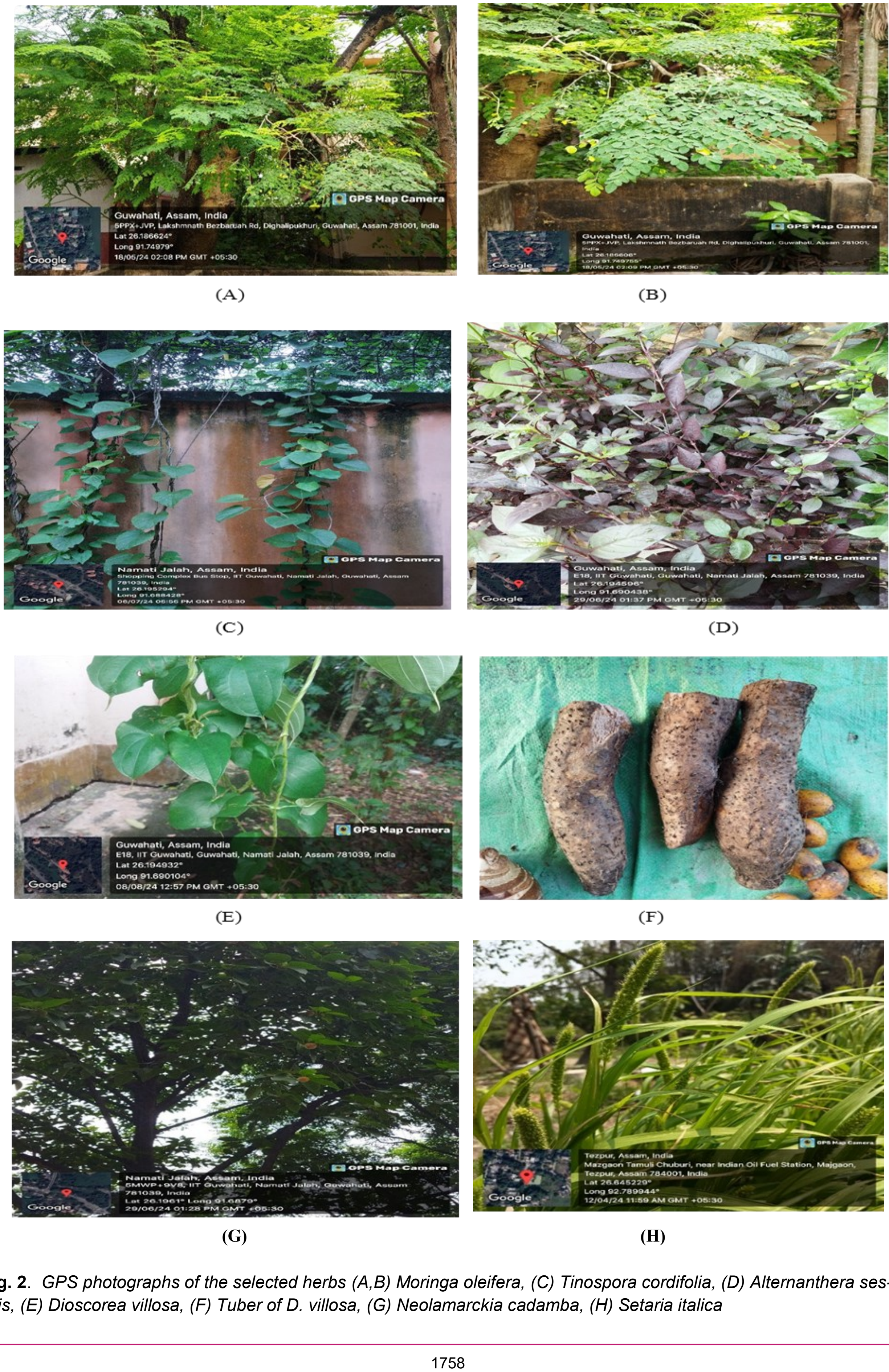


Fig. 2. *GPS photographs of the selected herbs (A,B) Moringa oleifera, (C) Tinospora cordifolia, (D) Alternanthera sessilis, (E) Dioscorea villosa, (F) Tuber of D. villosa, (G) Neolamarckia cadamba, (H) Setaria italica*

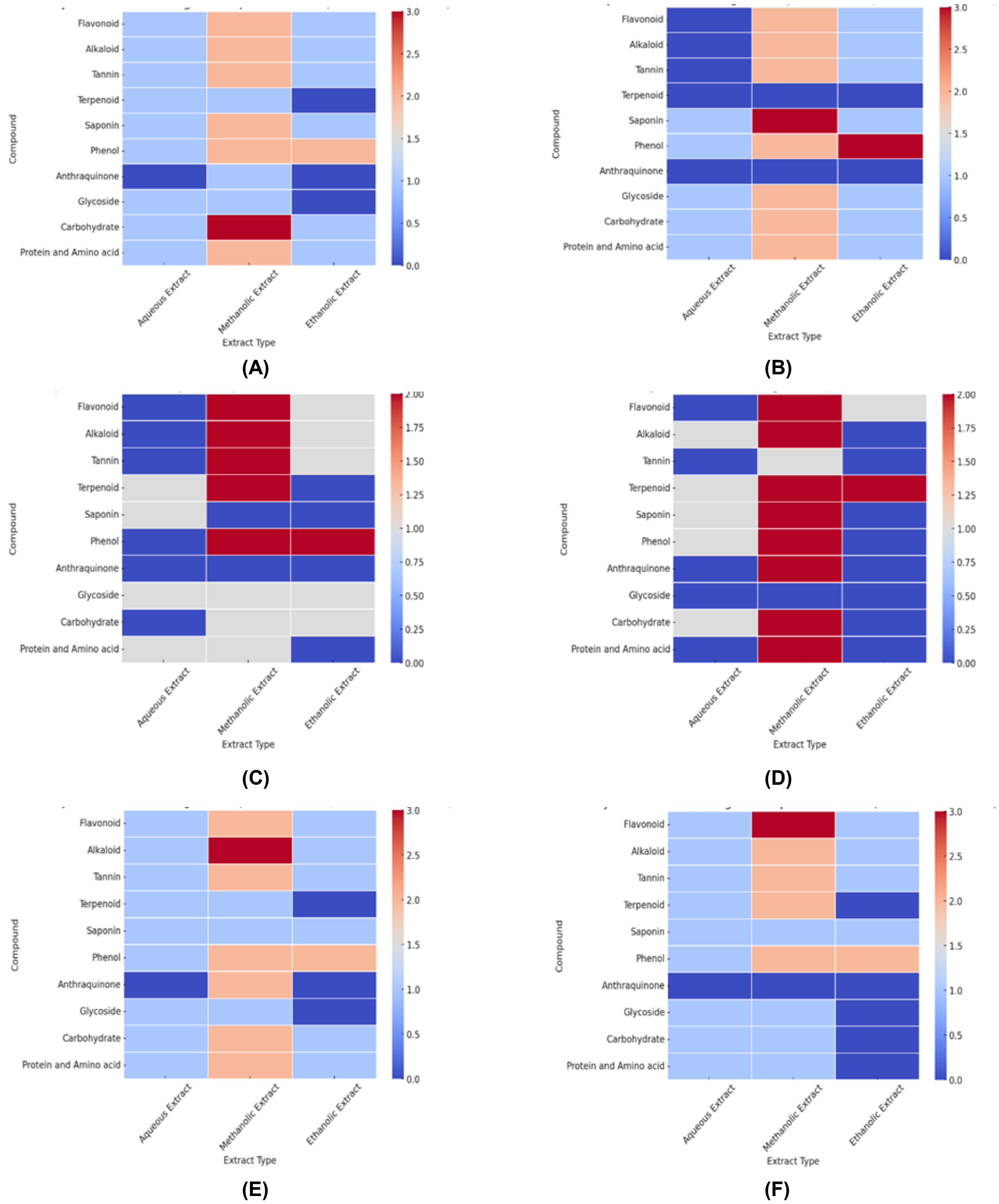
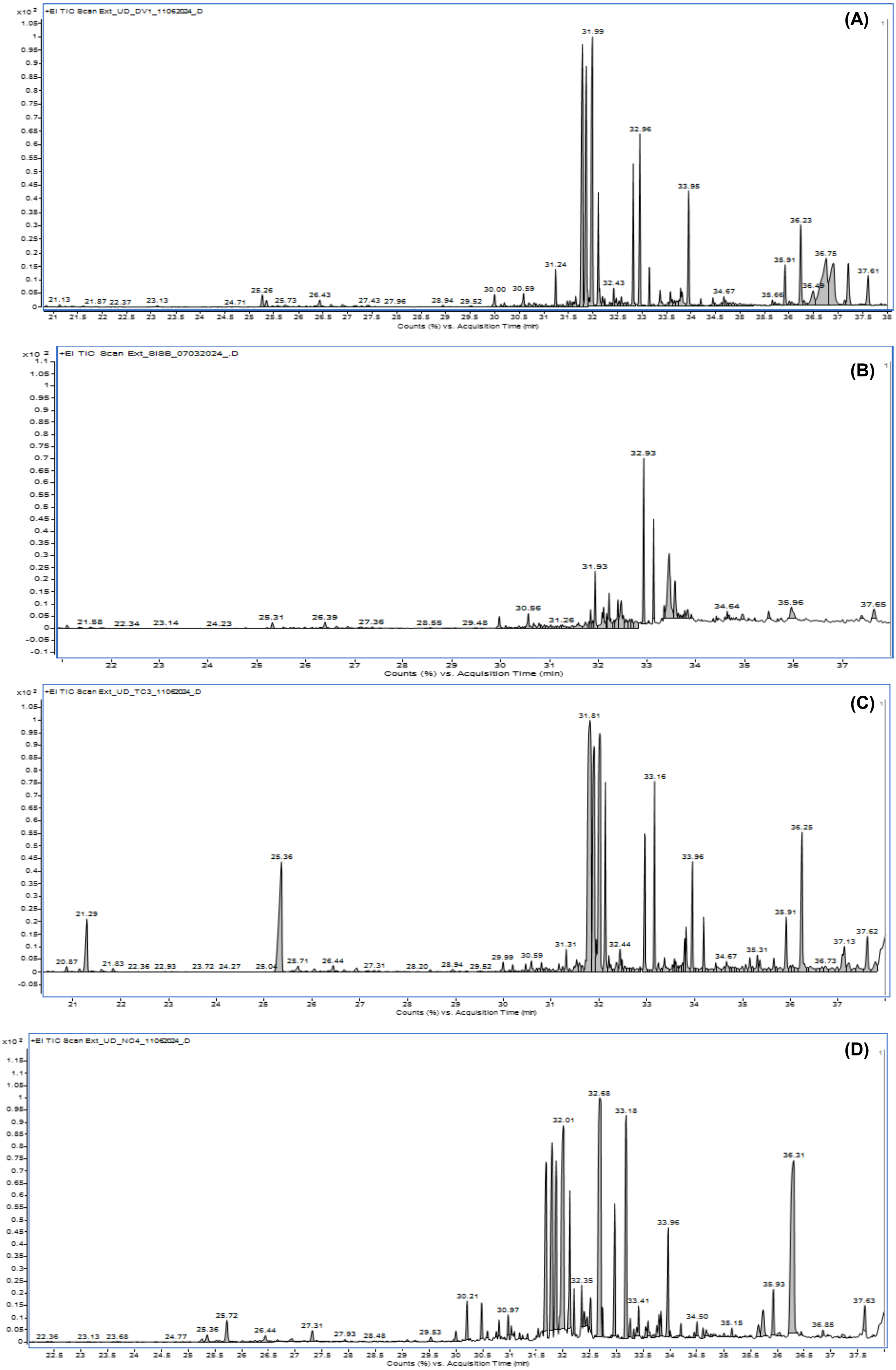


Fig. 3. *Heatmap analysis of qualitative phytochemical screening of selected herbs using three different solvents; (A) Dioscorea villosa, (B) Setaria italica, (C) Tinospora cordifolia, (D) Neolamarckia cadamba, (E) Alternanthera sessilis, and (F) Moringa oleifera*

declining towards baseline (107.29 ± 0.51 mg/dl) at 120 min (Table 5; Fig. 5).

In contrast, all plant extracts showed significantly lower glycemic responses than the glucose reference group ($p < 0.05$). *Dioscorea villosa* showed a moderate rise in blood glucose, peaking at 115.82 ± 0.59 mg/dl at 45 min, while *Setaria italica* peaked at 103.15 ± 0.16 mg/dl at 75 min. *T.cordifolia, N.cadamba, and A. sessilis* consistently showed lower glucose levels throughout the 120 min period, with peak values of 92–104 mg/dl. *Moringa oleifera* produced slightly higher values than other test plants but remained significantly lower than the glucose group. Overall, the plant extracts resulted in a blunted glycemic excursion compared to the reference food, confirming their potential to attenuate postprandial hyperglycemia.


(A)
+EI TIC Scan Ext_UD_DV1_11062024_D
31.99
32.96
33.95
36.23
35.91
36.75
37.61
31.24
32.43
34.67
35.66
36.49
21.13
21.87
22.37
23.13
24.71
25.26
25.73
26.43
27.43
27.96
28.94
29.52
30.00
30.59
Counts (%) vs. Acquisition Time (min)
(B)
+EI TIC Scan Ext_818B_07032024_.D
32.93
31.93
30.56
31.26
34.64
35.96
37.65
21.58
22.34
23.14
24.23
25.31
26.39
27.36
28.55
29.48
Counts (%) vs. Acquisition Time (min)
(C)
+EI TIC Scan Ext_UD_TO3_11062024_D
31.81
33.16
36.25
33.96
25.36
21.29
35.91
37.13
37.62
31.31
32.44
34.67
35.31
36.73
20.87
21.83
22.36
22.93
23.72
24.27
25.04
25.71
26.44
27.31
28.20
28.94
29.52
29.99
30.59
Counts (%) vs. Acquisition Time (min)
(D)
+EI TIC Scan Ext_UD_NO4_11062024_D
32.68
33.18
32.01
36.31
33.96
32.35
35.93
30.21
33.41
30.97
37.63
34.50
35.15
36.85
22.36
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Counts (%) vs. Acquisition Time (min)

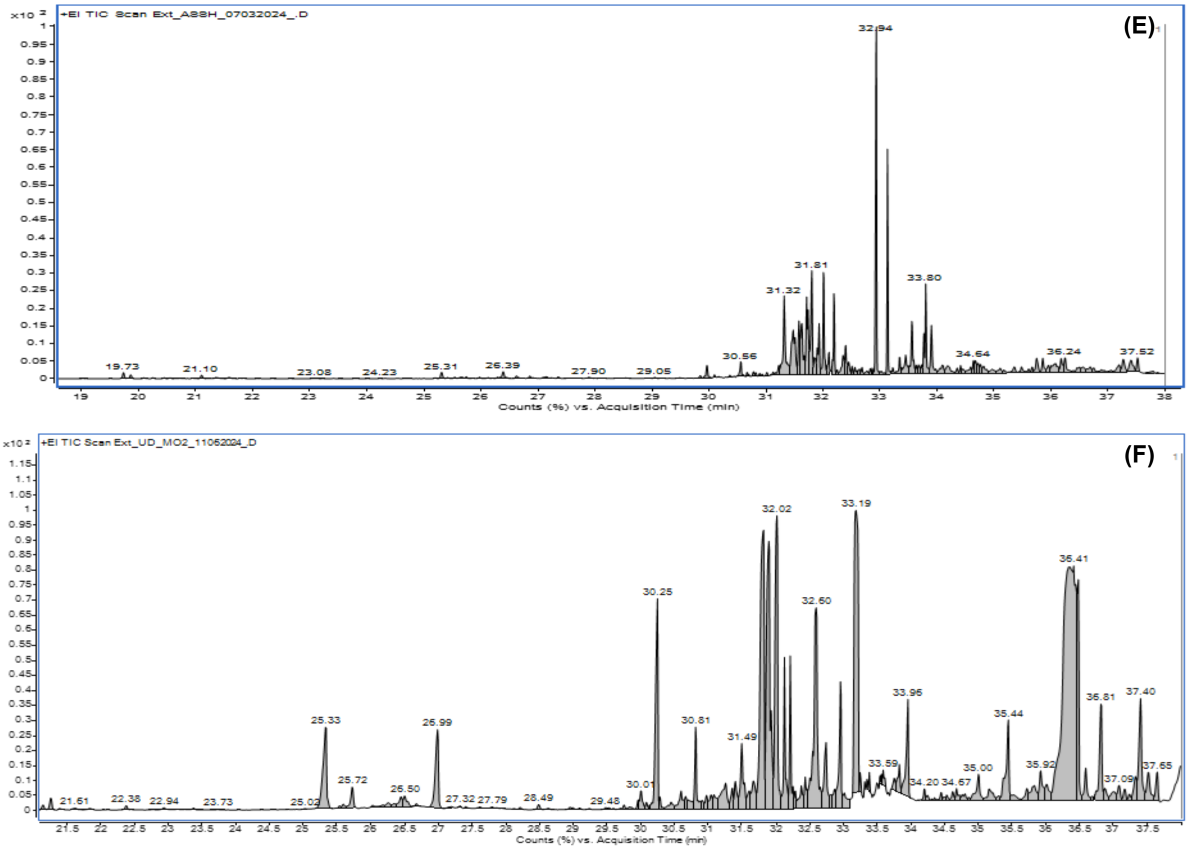

Fig. 4. GC-MS chromatogram of methanolic extracts of *(A) Dioscorea villosa, (B) Setaria italica, (C) Tinospora cordifolia, (D) Neolamarckia cadamba, (E) Alternanthera sessilis, and (F) Moringa oleifera*

Glycemic index (GI)

The incremental area under the curve (iAUC) was calculated for each group, and glycemic index (GI) values were derived relative to the glucose reference (GI = 100). All six plant extracts exhibited GI values below 55, indicating they are low-GI foods (Table 6).

Among the plants tested, *T. cordifolia* showed the lowest GI (35.68), followed closely by *N.cadamba* (38.54), *M. oleifera* (38.79), and *A. sessilis* (39.87). *D. villosa* (54.38) and *S. italica* (52.15) showed relatively higher GI values but still fell within the low-GI range.

DISCUSSION

This study presents the prevalence of diabetes mellitus and ethnobotanical knowledge of traditional plant use for glycemic control across different districts of Assam. Ten districts were approached, and a total of 437 responses were received, with Kamrup (n = 108 respondents), Sivsagar (n = 91 respondents), and Nalbari (n = 86 respondents) being the most responsive. This discrepancy highlighted the regional variability in the use of traditional plants for combating diabetes. While male dominance among respondents was observed in Kamrup and Nalbari, this was not reflected in the more gender-balanced participation in Sivsagar, suggesting some gender-based inequalities in health-seeking behaviour. As broad as it seems, men within the rural society suffer with complications affiliated with diabetes due to dietary habits and breaks from their socio-financial function (Ciarambino *et al*., 2022). Secondly, this male trend could be a reflection of socio-economic or cultural components where men are the main breadwinners and hence are in a high-stress environment inducing development of diabetes. Conversely, districts like Sivsagar, which have greater gender parity in the practice of traditional medicine, indicate that awareness of, and practice of, traditional medicine may be more widespread among the people.

In fact, the high prevalence of diabetes and pre-diabetes reported in districts like Kamrup and Nalbari indicates urbanization and lifestyle transition contributing towards metabolic diseases. Often, rapid urbanization is associated with shifts toward a westernised dietary pattern, reductions in opportunities for physical activity, and increased consumption of processed foods, all of which are risk factors for type 2 diabetes (Lieberman, 2003). These trends are in concordance with national statistics from India, which also detail an increase in the diabetes burden in urban centres owing to such lifestyle factors (Tandon *et al*., 2018). This lower prevalence in Dhubri and Karbi Anglong may be attributable to the protective effects of traditional diets, potentially greater levels of physical activity from agrari-

Table 2. List of medicinal plants used by the surveyed population across various districts

Sl no.	Scientific Name	Common name	Family	Plant Part Used	Mode of consumption	Tribe/ Community	% utilized by people studied
1	*Acorus calamus*	Sweet flag	Acoraceae	Root, Rhizome	The raw, partially grown flower stems are eaten in salads in the spring. The roots have a spicy, bitter, and sweet taste, and can be eaten. A paste of the roots mixed with milk is given to children to improve digestion.	Bodo, Assamese	21.3
2	*Adhatoda vasica*	Malabar nut	Acanthaceae	Leaves, flowers and bark	The leaves of the Malabar nut are used to make juice and cough syrups.	Bodo, Assamese, Deuri	23.7
3	*Aegle marmelos*	Bael or Bengal quince	Rutaceae	Leaves, Fruit	The plant is highly edible and the fruit is eaten raw or made into marmalades, jams, jellies and drinks.	Assamese	31.5
4	*Allium cepa*	Onion	Liliaceae	Bulb, whole plant	Onions are eaten raw, cooked and processed into different food products.	Assamese, Ahom, Mising, Deuri	42
5	*Allium sativum*	Garlic	Amaryllidaceae	Bulb, Root, whole plant	Garlic bulbs are eaten raw, cooked and processed into different food products.	Assamese, Ahom, Mising, Deuri	43.5
6	*Alternanthera sessilis*	Sessile Joyweed	Amaranthaceae	Whole plant	Used in salads, soups, and traditional Assamese dishes to help manage diabetes. The plant is boiled and consumed as a decoction.	Assamese, Ahom	45.2
7	*Aloe barbadensis*	Aloe vera	Asphodelaceae	Leaves	The gel from the leaves is consumed as a juice or tonic to aid digestion. Aloe vera gel is used as a flavoring component and preservative in some foods, such as milk, ice cream, and confectionery.	Assamese, Ahom	35
8	*Annona squamosa*	Custard apple	Annonaceae	Leaf, Fruit	Custard apples are peeled and eaten like a pear, with the fleshy insides being the most unique part. Frozen custard apple pulp can be blended with milk, yogurt, or vanilla ice cream, along with banana and pineapple.	Assamese, Ahom	38
9	*Asparagus racemosus*	Wild asparagus	Asparagaceae	Tubers, shoots	Young shoots are eaten cooked or raw. The tubers of this plant are also eaten to treat stomach issues, urinary tract stones, and thirst.	Assamese, Ahom,	42.3
10	*Azadirachta indica*	Neem	Meliaceae	Leaves, Bark	Neem leaves are fried and eaten in rice. The bark is used for brushing teeth.	Assamese, Ahom,	43
11	*Beta vulgaris*	Beet	Chenopodiaceae	Tuber, Leaf, root	The tuber is boiled in water and taken with rice. It can be eaten raw, included fresh in salads or blended into juice.	Assamese, Ahom,	23

Contd…..

Table 2. Contd…..

12	*Carica papaya*	Papaya	Caricaceae	Fruit, leaves	Papaya is used in the Assamese dish Amita aaru Maati Mahor Khar, which is made by pressure cooking papaya and black gram with water and salt, then adding it to a wok with mustard oil, ginger, and khar. It can be eaten fresh in salads or blended into juice.	Assamese, Ahom, Mis-ing, Deuri	25
13	*Centella asiatica*	Indian pen-nywort	Apiaceae	Leaves, shoots	The leaves and young shoots of the plant are eaten as a vegetable. The leaves are used to make a liver tonic by cooking them with small fish in a curry. To treat stomach ulcers and urinary tract infections, the plant can be boiled, strained, and mixed with honey and drunk in the morning.	Assamese, Ahom, Mis-ing, Deuri	15
14	*Curcuma longa*	Turmeric	Zingiberace-ae	Rhi-zome	Turmeric is a key ingredient in curry powders and pastes. It is also con-sumed raw early in the morning.	Assamese, Ahom, Mis-ing, Deuri	53
15	*Dioscorea sp.*	Yam		Tuber	They are usually boiled, added to lentils, and sometimes smoked. Yams are boiled and mashed into a paste or dough. They are also fried, roasted, or baked.	Assamese, Ahom, Mis-ing, Deuri	58
16	*Emblica officinalis*	Indian gooseberry	Phyl-lanthaceae	Fruit	A sweet, homemade candy is made from amla, jaggery, and salt that is used to fight anemia. The candy is made by cutting the amla into small pieces, cooking it until dry, and then mixing it with jaggery and salt to form balls. "Amlokhi aakhon" A gooseberry soup that is often served before a meal. Amla is also used in other dishes such as khar, baabhgajor lagot kukura, maasor tenga, and xaak aru bhaji.	Assamese	42
17	*Gymnema sylvestre*	Gudmar	Apocynace-ae	Leaves	The leaves are dried and con-sumed into powdered form with warm water early morning to re-duce formation of phlegm and-cough.	Assamese, Bodo	34
18	*Ipomoea batatas*	Sweet potato	Convolvu-laceae	Tuber, Root	It is eaten boiled or baked and is a popular snack. During Magh Bihu, sweet potatoes are often grilled or boiled, peeled, and served with hot milk and sugar or jaggery.	Assamese, Ahom, Mis-ing, Deuri	28
19	*Mangifera indica*	Mango	Anacardi-aceae	Fruits, leaves	Raw mango is eaten as slices sprinkled with salt and chili, or add-ed to jhaal muri or chanachur. The fruit is also used for making raw slices in brine, amchur, pickle, mu-rabba, chutney.	Assamese, Ahom, Mis-ing, Deuri	36

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Table 2. Contd…..

20	*Moringa oleifera*	Drumstick tree	Moringaceae	Leaves, Pods	Leaves are eaten as a vegetable, made into soups, or dried into powder to reduce blood sugar levels. Pods are cooked in curries and stews.	Assamese, Ahom, Deuri	52
21	*Momordica charantia*	Bitter gourd	Cucurbitaceae	Fruit	In Assamese households, bitter gourd is often deep-fried until crispy and eaten with rice, lentils, or fish. An Assamese bitter gourd salad, or titakerala salad, is made by shallow-frying the bitter gourd, then adding onions, tomatoes, green chilies, roasted peanuts, ginger, and mustard oil. The bitter gourd rounds should be sliced as thin as possible. Bitter gourd is also blend into a juice and drank by people.	Assamese, Ahom,	37.5
22	*Murraya koenigii*	Curry leaves	Rutaceae	Leaves	The tender leaves are ground into a paste and used to cook chicken with black pepper. Tadka is made by sautéing curry leaves, mustard seeds, cumin, and other spices in ghee or mustard oil. It is also made into a tonic and the jiuce of fresh leaves is drank with lime and sugar.	Assamese, Ahom, Mising, Deuri	64
23	*Neolamarckia cadamba*	Kadamba	Rubiaceae	Bark, leaves	The bark decoction is consumed to regulate blood sugar levels. Leaves are also used in herbal infusions for diabetes management.	Assamese, Ahom, Mising	48
24	*Nigella sativa*	Black cumin	Ranunculaceae	Seeds	Black cumin seeds are used in curries, dals, vegetables, chutneys, and yogurts. They can be dry roasted or fried in oil to give a more intense aroma. Black cumin seeds are sprinkled on breads for flavor and texture.	Assamese, Ahom, Mising, Deuri	53
25	*Ocimum sanctum*	Tulsi	Lamiaceae	Leaves	The leaves is blended with green tea leaves and consumed as tea. It is also consumed by taking a few leaves of Tulsi along with honey to relieve cough and flu as it improves immune health.	Assamese,	36
26	*Pterocarpus marsupium*	Indian kino tree	Fabaceae	Heartwood, bark, flowers	The flowers are consumed as a remedy due to its bitter taste which improve their appetite and cause flatulence. The wood is infused with with water and consumed.	Assamese, Ahom, Mising, Deuri	23
27	*Setaria italica*	Foxtail millet	Poaceae	Grains	Used as a staple food, beneficial in controlling blood sugar levels. It is consumed as porridge, flour-based dishes, and traditional rice substitutes.	Assamese, Bodo	52
28	*Syzygium cumini*	Jamun	Myrtaceae	Fruits, Seeds, Leaves	Fully ripened fruits are eaten as fresh fruit and are also processed into beverages like jelly, jam, squash, wine, vinegar and pickles. Jamun fruits are also used to prepare vinegar.	Assamese, Ahom,	64

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Table 2. Contd…..

29	*Terminalia chebula*	Haritaki	Combretaceae	Bark, Fruit	The bark is directly chewed by mouth to improve digestion and reduce constipation.	Assamese, Ahom, Mising, Deuri	33
30	*Tinospora cordifolia*	Giloy	Menispermaceae	Stem, leaves	It is consumed by boiling the stem and making a tea. The tea is made palatable by adding honey or sugar candy. The stem is also dried and made into powder which is consumed by people with warm water or honey in the morning. Fresh leaves and stem are also soaked overnight, crushed, and boiled in the morning in one glass of water until it gets half. The mixture is then strained and drunk.	Assamese, Ahom, Mising, Deuri	58
31	*Trigonella foenum-graecum*	Fenugreek	Fabaceae	Seeds, leaves	Used as a spice in vegetable dishes, especially those with watery vegetables. It is also used as a preservative in pickles.	Assamese,	54
32	*Vachellia nilotica*	Babul	Fabaceae	Bark	Babul is used for gargling in the diseases of mouth ulcers and bleeding gums. It is boiled with water and consumed early in morning.	Assamese	21

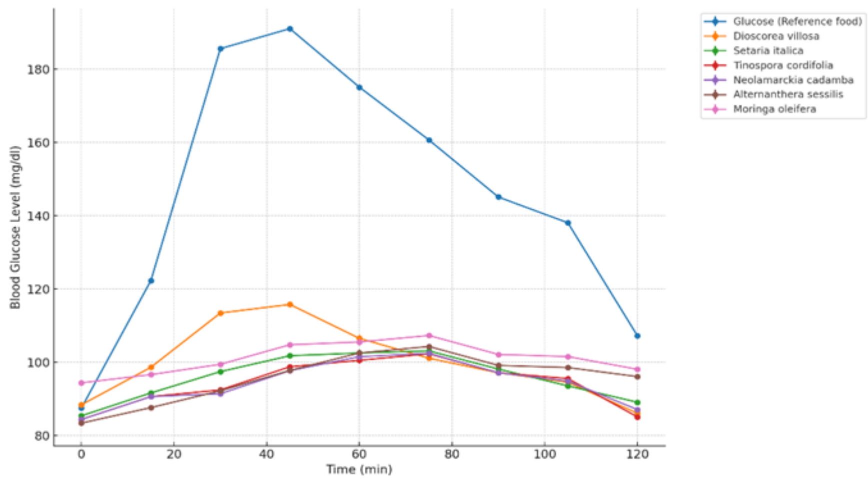


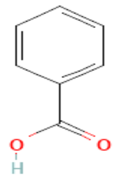
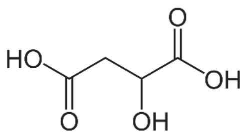
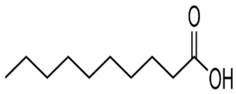
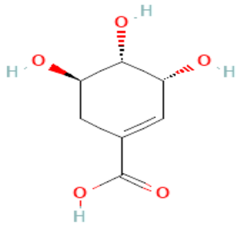
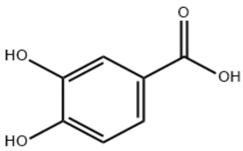
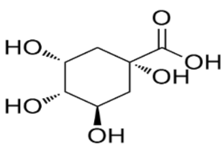
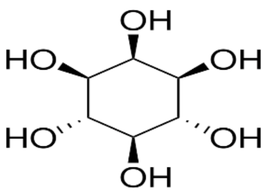
Fig. 5. *Graph for blood sugar levels (mg/dL) in rats with respect to time after exposure to glucose and plant extracts for 120 minutes.*

an livelihoods, and reduced exposure to ultra-processed, high-calorie foods (Pressler *et al*., 2022).
Deep-rooted ethnobotanical knowledge for anti-diabetic plants were noted. Among these, a few of the most commonly employed plants are: *Gymnema sylvestre* (Gudmar), *T.cordifolia* (Giloy), *Trigonella foenum-graecum* (Fenugreek)*, Azadirachta indica* (Neem), *and Curcuma longa* (Turmeric), D.sp. (Yam), *Alternanthera sessilis* (Keremak), *M. oleifera* (Shajna). These plants have also been well recorded in Ayurvedic and ethno-medicinal literature for their anti-diabetic properties. The knowledge at the community level regarding the use of these botanical species reflects a well-established tradition of addressing chronic ailments with natural treatments (Karunamoorthi *et al*., 2013; Jamal, 2023). An example of this is *Gymnema sylvestre*, commonly known as "gurmar," which translates to "sugar destroyer," owing to its bioactive constituents, such as gymnemic acids, that impede glucose absorption in the intestine while simultaneously improving insulin activity (Shanmugasundaram *et al*., 1990). Correspondingly, *T.cordifolia* modulates the immune system and exhibits anti-inflammatory properties that could play a role in reducing insulin resistance, an overarching characteristic of type 2 diabetes (Kannadhasan and Venkataraman, 2013). This underscores the importance of protecting indigenous knowledge, as it may provide crucial insights for effectively managing diabe-

Table 3. List of pharmaceutical drugs commonly used by diabetic patients along with their side effects

Medication class	Mechanism of action	Common use	Side effects	Typical dosage	Examples	Additional observations	References
Biguanides	Enhances insulin sensitivity and curbs hepatic glucose production.	Type 2 diabetes	Gastrointestinal issues (nausea, diarrhea), lactic acidosis (rare).	500-2000 mg per day, typically in divided doses.	Metformin	Often the first-line treatment for Type 2 diabetes.	Jangaard *et al., 1968; Mehnert 2001;* Di magno *et al.*, 2022
Sulfonylureas	Promote the pancreas to secrete additional insulin, often paired with other	Type 2 diabetes	Weight gain, risk of hypoglycemia.	1-2 times daily, dose depends on the specific drug.	Glipizide, Glimepiride, Gliclazide	Should be taken with food to minimize the risk of hypoglycemia.	Levine and Sobel, 1957; Lebovitz and Feinglos, 1978; Zimmerman, 1997
Meglitinides	Induce short-lived insulin secretion from the pancreas.	Type 2 diabetes	Hypoglycemia, weight gain.	Taken before meals, dosing varies based on blood sugar levels.	Repaglinide, Nateglinide	Shorter action compared to sulfonylureas, allowing flexibility in meal timing.	Landgraf, 2000; Malaisse, 2003
Thiazolidinediones (TZDs)	Improve insulin sensitivity in muscles and adipose tissues; limited due to side	Type 2 diabetes	Weight gain, fluid retention, increased risk of heart failure.	Typically 15-45 mg once daily.	Pioglitazone, Rosiglitazone	Requires monitoring for heart-related issues and liver function.	Reginato and Lazar, 1999; Hauner, 2002
DPP-4 Inhibitors (Gliptins)	Boost incretin hormones, enhancing insulin output and lowering glucagon lev-	Type 2 diabetes	Nasopharyngitis, headache, potential for pancreatitis.	Once daily, dosage varies depending on kidney function.	Sitagliptin, Saxagliptin	May be beneficial for patients who cannot tolerate other drugs.	Green *et al.,* 2007; Duez *et al., 2012*; Makrilakis, 2019
GLP-1 Receptor agonists	Imitate GLP-1 hormone, encouraging insulin secretion and curbing	Type 2 diabetes	Nausea, vomiting, diarrhea, possible risk of thyroid tumors.	Weekly or daily injections, depending on the drug.	Exenatide, Liraglutide, Dulaglutide	Also used for weight loss in some patients with Type 2 diabetes.	Garber, 2012; Cornell, 2020
SGLT2 Inhibitors	Block glucose reabsorption in the kidneys, increasing glucose excretion via urine.	Type 2 diabetes	Increased risk of urinary tract infections, dehydration.	Once daily, dosage typically 10-25 mg.	Empagliflozin, Canagliflozin, Dapagliflozin	Can reduce the risk of cardiovascular events in Type 2 diabetes patients.	Ferrannini and Solini, 2012; Vallon, 2015; Vallon, 2024
Insulin	Crucial for managing Type 1 and advanced Type 2 diabetes by lowering blood sugar levels.	Type 1 and advanced Type 2 diabetes	Risk of hypoglycemia, weight gain.	Dosage highly individualized based on glucose monitoring.	Various types (Rapid -acting, Long-acting, etc.)	Essential for Type 1 diabetes, often combined with oral medications for Type 2.	Bouckaert and de Duve, 1947; White, 2017; Petersen and Shulman, 2018
Insulin analogues	Genetically engineered insulin variants for more stable and predictable effects.	Type 1 and Type 2 diabetes	Hypoglycemia, injection site reactions.	Doses adjusted based on blood glucose readings.	Insulin aspart, Insulin lispro, Insulin glargine	Designed to mimic the body's natural insulin release patterns.	Tompkins *et al.,* 1981; Mathieu *et al.,* 2017; Rodbard and Rodbard, 2020

Table 4. Principal bioactive marker components detected in the methanolic extract of selected plants through GC-MS

Dioscorea villosa					
Compound name	**Chemical formula**	**Molecular structure**	**RT**	**Area sum %**	**Biological activity**
Benzoic Acid	$C_7H_6O_2$		**19.05**	**0**	Antimicrobial preservative, antifungal, bacteriostatic (pH-dependent), anti-inflammatory and antioxidant in derivatives (Park *et al*., 2001; Issa and Mohammed, 2025)
Malic acid	$C_4H_6O_5$		**25.26**	**0.47**	TCA-cycle intermediate, metabolic buffer, supports energy metabolism, regulates pH, inhibits digestive enzymes (α-glucosidase, α-amylase, lipase) (Alakolanga *et al*., 2015; Arslan, 2021)
Dodecanoic acid (Lauric acid)	$C_{12}H_{24}O_2$		**29.09**	**0.02**	Medium-chain fatty acid with antimicrobial activity, potential drug delivery applications (Ameena *et al*., 2024)
Shikimic acid	$C_7H_{10}O_5$		**31.24**	**0.78**	Antiviral, antibacterial, antioxidant, anti-inflammatory, hypolipidemic, neuroprotective, skin- and bone-protective (Bochkov *et al*., 2012; Gandhi *et al*., 2023)
Protocatechoic acid	$C_7H_6O_4$		**31.33**	**0.07**	Antioxidant, anti-inflammatory, antihyperglycemic, neuroprotective, chemopreventive, antiproliferative, antimicrobial (Masella *et al*., 2012; Semaming *et al*., 2015; Cadena-Iñiguez *et al*., 2024)
Quinic acid	$C_7H_{12}O_6$		**31.65**	**0.36**	Antioxidant, antidiabetic, anticancer, antimicrobial, antiviral, analgesic, enhances insulin secretion and mitochondrial function (Heikkilä *et al*., 2019; Benali *et al*., 2024; Heena *et al*., 2024)
Myo-inositol	$C_6H_{12}O_6$		**33.14**	**0.78**	Secondary-messenger in signal transduction, supports insulin sensitivity, neurotransmitter signaling, GABA modulation, neuro-protective (Ortmeyer, 1996; Carlomagno *et al*., 2012; Werner and Froehlich, 2016)

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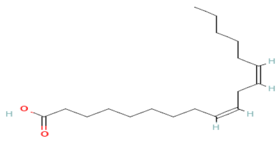
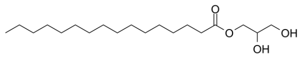
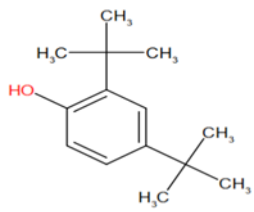
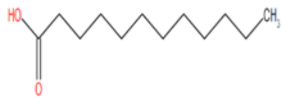
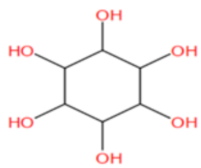
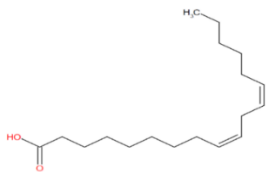
Linoleic acid	$C_{18}H_{32}O_2$		**33.79**	**1.04**	Essential fatty acid; precursor of EPA & DHA; anti-inflammatory, cardioprotective, neuroprotective; supports immune modulation and reduces risk of cardiovascular disease (Kim *et al*., 2014; Dittrich *et al*., 2015; Yuan *et al*., 2022)
1-Monopalmitin	$C_{16}H_{32}O_4$		**35.91**	**1.23**	Inhibits P-glycoprotein in intestinal cells, acts as a food emulsifier, serves as a biomarker for metabolic stress (Konishi *et al*., 2004; Bunka *et al*., 2007)
		Setaria italica			
Name of the compound	**Chemical formula**	**Chemical structure**	**RT Value**	**Area %**	**Biological activity**
2,4-Di-tert-butylphenol	($C_{14}H_{22}O$)		25.74	0.05	Antioxidant and broad-spectrum antimicrobial (antibacterial and antifungal), with reported anti-inflammatory effects across in vitro and in vivo models (Zhao *et al*., 2020; Ayswarya *et al*., 2022; Rouvier *et al*., 2024)
Dodecanoic acid/ Lauric acid	($C_{12}H_{24}O_2$)		29.05	0.02	Medium-chain fatty acid with antimicrobial activity, potential drug delivery applications (Ameena *et al*., 2024)
Myo-inositol	($C_6H_{12}O_6$)		33.13	1.99	Secondary-messenger in signal transduction, supports insulin sensitivity, neurotransmitter signaling, GABA modulation, neuro-protective (Ortmeyer, 1996; Carlomagno *et al*., 2012; Werner and Froehlich, 2016)
Linoleic acid	$C_{18}H_{32}O_2$		33.45	6.9	Essential fatty acid; precursor of EPA & DHA; anti-inflammatory, cardioprotective, neuroprotective; supports immune modulation and reduces risk of cardiovascular disease (Kim *et al*., 2014; Dittrich *et al*., 2015; Yuan *et al*., 2022)

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Table 4. Contd….

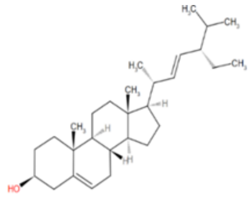
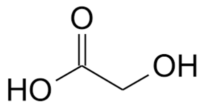
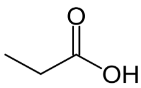
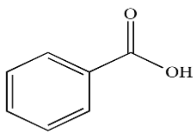
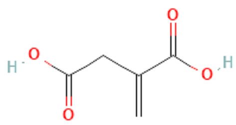
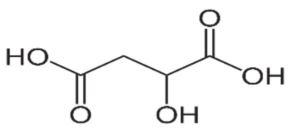
Stigmasterol	($C_{29}H_{48}O$)		34.95	0.39	Broad anti-inflammatory, antioxidant, anticancer, immunomodulatory, anti-microbial, and neuropro-tective activities (Bakrim *et al*., 2022; Goswami *et*
		Tinospora cordifolia			
Compound name	**Chemical formula**	**Chemical structure**	**RT**	**Area sum %**	**Biological activity**
Glycolic acid	$C_2H_4O_3$		14.1	0.01	Exfoliates by weakening intercellular cohesion, stimu-lates fibroblast proliferation, increases collagen synthe-sis, enhances hyaluronic acid expression, shows pH-dependent antibacterial ac-tivity (Fartasch *et al*., 1997; Kim and Won, 1998; Bern-stein *et al*., 2001; Valle-González *et al*., 2020)
Propanoic acid	$C_3H_6O_2$		14.41	0.01	Lowers liver and plasma fatty acid levels, reduces food intake, exerts immuno-suppressive effects, im-proves insulin sensitivity, and has antimicrobial activity including against MRSA (Al-Lahham *et al*., 2010; Ahmed *et al*., 2012)
Benzoic acid	$C_7H_6O_2$		19.05	0	Antimicrobial preservative, antifungal, bacteriostatic (pH -dependent), anti-inflammatory and antioxidant in derivatives (Park *et al*., 2001; IssaandMohammed, 2025)
Itaconic acid	$C_5H_6O_4$		21.59	0.1	Acts as an immunometabo-lite with anti-inflammatory, antimicrobial, antioxidant, and antiviral effects through mechanisms like promoting ROS via PPP, inhibiting TET2 and succinate dehy-drogenase, activating Nrf2/ ATF3, and suppressing NLRP3 inflammasome (Zhu *et al*., 2021; Yang *et al*., 2023; Al Mazraani *et al*., 2025)
Malic acid	$C_4H_6O_5$		25.36	5.3	TCA-cycle intermediate, metabolic buffer, supports energy metabolism, regu-lates pH, inhibits digestive enzymes (α-glucosidase, α-amylase, lipase) (Alakolanga *et al*., 2015; Arslan, 2021)

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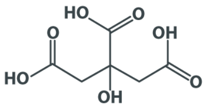
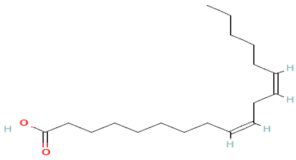
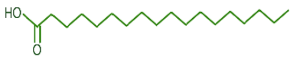
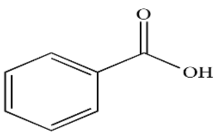
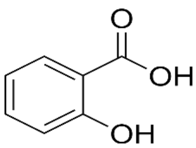
Table 4. Contd….

Citric acid	$C_6H_8O_7$		30.89	0.14	Serves as a central TCA cycle intermediate regulating metabolism, allosterically inhibits phosphofructokinase, functions as a metal ion chelator and pH buffer, and contributes to bone mineral stabilization (Nangare *et al*., 2021; Książek, 2023)
Linoleic acid	$C_{18}H_{32}O_2$		33.79	0.55	Essential fatty acid; precursor of EPA & DHA; anti-inflammatory, cardioprotective, neuroprotective; supports immune modulation and reduces risk of cardiovascular disease (Kim *et al*., 2014; Dittrich *et al*., 2015; Yuan *et al*., 2022)
9-Octadecenoic acid (Oleic acid)	$C_{18}H_{34}O_2$		33.82	0.88	Lowers LDL cholesterol, reduces inflammation, protects against insulin resistance and endothelial dysfunction, and exhibits antioxidant and antimicrobial activities (Perdomo *et al*., 2015; Santa-María *et al*., 2023; Ramadan *et al*., 2024)
Stearic acid	$C_{18}H_{36}O_2$		33.96	1.92	Neutral effect on cholesterol; structural component of membranes; energy source; exhibits mild antibacterial and antifungal activity (Bonanome and Grundy, 1988; Schneider *et al*., 2000; Tahlan *et al*., 2014)
		Neolamarckia cadamba			
Compound name	**Chemical formula**	**Chemical structure**	**RT**	**Area sum %**	**Biological activity**
Benzoic Acid	$C_7H_6O_2$		19.06	0.03	Antimicrobial preservative, antifungal, bacteriostatic (pH-dependent), anti-inflammatory and antioxidant in derivatives (Park *et al*., 2001; Issaand Mohammed, 2025)
Salicylic acid	$C_7H_6O_3$		21.78	0.01	Anti-inflammatory, analgesic, cardioprotective, antitumor, keratolytic, keratoplastic, comedolytic, antimicrobial, exfoliating, delays wound healing, modulates bacterial resistance and biofilm formation (Gupta *et al*., 2013; Arif, 2015; Lu *et al*., 2019; Ding *et al*., 2023)

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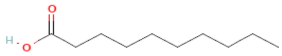
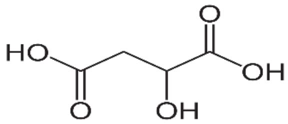
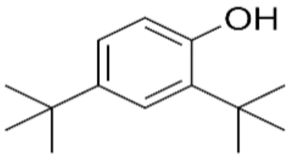
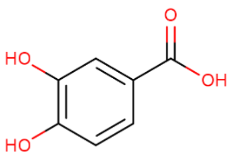
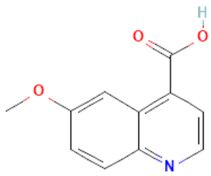
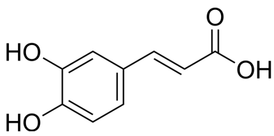
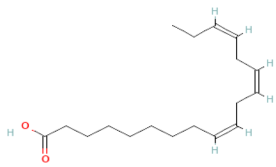
Decanoic acid	$C_{10}H_{20}O_2$		24.54	0	Exhibits antimicrobial, anti-fungal, anti-inflammatory, metabolic, and anti-tumor effects, including inhibition of mTORC1 and c-Met signaling (Warren *et al*., 2020; Mett and Müller, 2021; Wu *et al*., 2023; Yang *et al*., 2023)
Malic acid	$C_4H_6O_5$		25.26	0.05	TCA-cycle intermediate, metabolic buffer, supports energy metabolism, regulates pH, inhibits digestive enzymes (α-glucosidase, α-amylase, lipase) (Alakolanga *et al*., 2015; Arslan, 2021)
2,4-Di-tert-butylphenol	$C_{14}H_{22}O$		25.82	0.01	Antioxidant and broad-spectrum antimicrobial (antibacterial and antifungal), with reported anti-inflammatory effects across in vitro and in vivo models (Zhao *et al*., 2020; Ayswarya *et al*., 2022; Rouvier *et al*., 2024)
Protocatechoic acid	$C_7H_6O_4$		31.34	0.05	Antioxidant, anti-inflammatory, antihyperglycemic, neuroprotective, chemopreventive, antiproliferative, antimicrobial (Masella *et al*., 2012; Semaming *et al*., 2015; Cadena-Iñiguez *et al*., 2024)
Quininic acid	$C_7H_{12}O_6$		31.68	2.27	Antioxidant, antidiabetic, anticancer, antimicrobial, antiviral, analgesic, enhances insulin secretion and mitochondrial function (Heikkilä *et al*., 2019; Benali *et al*., 2024; Heena *et al*., 2024)
Caffeic acid	$C_9H_8O_4$		33.41	0.28	Acts as a potent antioxidant, anti-inflammatory, antimicrobial, antidiabetic, anticancer, immunomodulatory, and hepatoprotective agent (Espíndola *et al*., 2019; Aijaz *et al*., 2022)
α-Linolenic acid	$C_{18}H_{30}O_2$		33.83	0.19	Essential fatty acid; precursor of EPA & DHA; anti-inflammatory, cardioprotective, neuroprotective; supports immune modulation and reduces risk of cardiovascular disease (Kim *et al*., 2014; Dittrich *et al*., 2015; Yuan *et al*., 2022)

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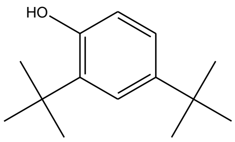
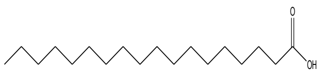
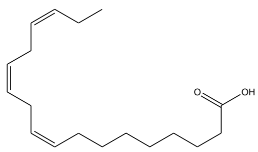
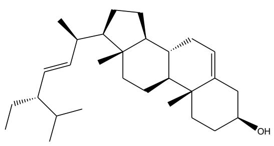
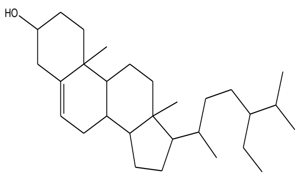
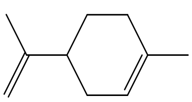
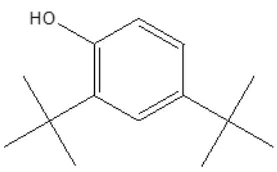
		Alternanthera sessilis			
Name of the compound	**Chemical formula**	**Chemical structure**	**RT**	**Area sum %**	**Biological activity**
2,4-Di-tert-butylphenol	$C_{14}H_{22}O$		25.74	0.05	Antioxidant and broad-spectrum antimicrobial (antibacterial and antifungal), with reported anti-inflammatory effects across in vitro and in vivo models (Zhao *et al*., 2020; Ayswarya *et al*., 2022; Rouvier *et al*., 2024)
Octadecanoic acid (Stearic acid)	$C_{18}H_{36}O_2$		33.56	1.65	Neutral effect on cholesterol; structural component of membranes; energy source; exhibits mild antibacterial and antifungal activity (Bonanome and Grundy, 1988; Schneider *et al*., 2000; Tahlan *et al*., 2014)
α-Linolenic acid, TMS derivative	$C_{21}H_{42}O_2Si$		33.8	2.35	Essential fatty acid; precursor of EPA & DHA; anti-inflammatory, cardioprotective, neuroprotective; supports immune modulation and reduces risk of cardiovascular disease (Kim *et al*., 2014; Dittrich *et al*., 2015; Yuan *et al*., 2022)
Stigmasterol	$C_{29}H_{48}OC$		34.19	0.65	Broad anti-inflammatory, antioxidant, anticancer, immunomodulatory, antimicrobial, and neuroprotective activities (Bakrim *et al*., 2022; Goswami *et al*., 2023)
β-Sitosterol, TMS derivative	$C_{33}H_{60}O_2Si$		36.56	0.3	Anti-inflammatory and antioxidant actions via NF-κB and MAPK pathway modulation and cytokine regulation (Rashed, 2020; Zhang *et al*., 2023)
		Moringa oleifera			
Compound name	**Chemical formula**	**Chemical structure**	**RT**	**Area sum %**	**Biological activity**
Limonene	$C_{10}H_{16}$		12.86	0.01	Exhibits antimicrobial, antioxidant, anti-inflammatory and anticancer activities (**Mukhtar *et al*., 2018;** Anandakumar *et al*., 2021; **S Devi *et al*., 2025**
2,4-Di-tert-butylphenol	$C_{14}H_{22}O$		25.75	0.07	Antioxidant and broad-spectrum antimicrobial (antibacterial and antifungal), with reported anti-inflammatory effects across in vitro and in vivo models (Zhao *et al*., 2020; Ayswarya *et al*., 2022; Rouvier *et al*., 2024)

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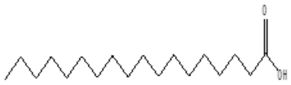
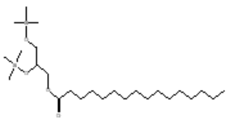
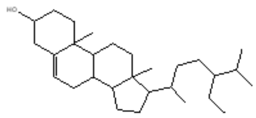
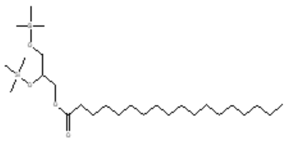
Octadecanoic acid	$C_{18}H_{36}O_2$		35.36	0.54	Neutral effect on cholesterol; structural component of membranes; energy source; exhibits mild antibacterial and antifungal activity (Bonanome and Grundy, 1988; Schneider *et al*.,
α-Linolenic acid, TMS derivative	$C_{21}H_{38}O_2Si$		33.8	0.94	Essential fatty acid; precursor of EPA & DHA; anti-inflammatory, cardioprotective, neuroprotective; supports immune modulation and reduces risk of cardiovascular disease (Kim *et al*., 2014; Dittrich *et al*., 2015; Yuan *et al*., 2022)
1-Monopalmitin, 2TMS derivative	$C_{25}H_{54}O_4Si_2$		35.75	0.47	Inhibits P-glycoprotein in intestinal cells, acts as a food emulsifier, serves as a biomarker for metabolic stress (Konishi *et al*., 2004; Bunka *et al*., 2007)
β-Sitosterol	$C_{29}H_{50}O$		35.96	0.73	Anti-inflammatory and anti-oxidant actions via NF-κB and MAPK pathway modulation and cytokine regulation (Rashed, 2020; Zhang *et al*., 2023)
Glycerol monostearate, 2TMS derivative	$C_{27}H_{58}O_4Si_2$		37.53	0.32	Functions as oleogelator enhancing oil-binding and stability, increases hardness and viscosity in bigels, enables controlled release of bioactives, aggravates reproductive toxicity with phthalates (Gao *et al*., 2016; Lu *et al*., 2022 Malvano *et al*., 2024).

Table 5. Blood glucose levels (in mg/dL) after administration of glucose and plant extracts at various time intervals.

Time (in mins)	Blood glucose levels (in mg/dl ± SE)						
	Glucose (Reference food)	***Dioscorea villosa***	***Setaria italica***	***Tinospora cordifolia***	***Neolamacrck-ia cadamba***	***Alternanthe-ra sessilis***	***Moringa oleifera***
0	87.54±0.42	88.43±0.74	85.43±0.74*	84.45±0.74*	84.43±0.74*	83.43±0.74*	94.43±0.74*
15	122.33±0.62	98.67±0.48**	91.67±0.48**	90.67±0.48**	90.67±0.48**	87.67±0.48**	96.67±0.48**
30	185.63±0.11	113.49±0.27**	97.49±0.27***	92.49±0.27**	91.46±0.27***	92.25±0.27**	99.49±0.27**
45	191.09±0.08	115.82±0.59**	101.82±0.59**	98.82±0.59**	97.75±0.59**	97.82±0.59**	104.82±0.59**
60	175.12±0.13	106.57±0.94**	102.57±0.94***	100.57±0.94**	101.57±0.94**	102.57±0.94**	105.57±0.94**
75	160.72±0.72	101.15±0.16*	103.15±0.16*	102.35±0.16*	102.48±0.16*	104.35±0.16*	107.35±0.16*
90	145.13±0.38	97.18±0.22**	98.18±0.22**	97.18±0.22**	97.18±0.22*	99.18±0.22*	102.18±0.22*
105	138.11±0.47	94.6±0.31*	93.6±0.31*	95.6±0.31*	94.9±0.31*	98.6±0.31*	101.6±0.31*
120	107.29±0.51	86.13±0.17*	89.13±0.17*	85.13±0.17*	87.13±0.17*	96.13±0.17*	98.13±0.17*

Values are represented as mean± mean standard error, N=10, values are significant at P<0.05 (* indicate p<0.05, **p<0.01, ***p<0.001 and compared to the values of the reference food group using two-way ANOVA)

Table 6. Glycemic index of the six selected herbs most commonly used by the surveyed population

Plant species	Current GI
Dioscorea villosa	54.38
Setaria italica	52.15
Tinospora cordifolia	35.68
Neolamarckia cadamba	38.54
Alternanthera sessilis	39.87
Moringa oleifera	38.79

tes in a sustainable and accessible manner (Heywood, 2011).

Furthermore, knowledge of the botanical resources used varies from one district to another. Relatively more rural districts like Dhubri and Karbi Anglong have relied more on locally sourced plant material, as has been the case for generations. In contrast, urban dwellers, such as those in Kamrup, tend to combine traditional medicine with allopathic treatments and view health management from an integrative perspective (Sen and Chakraborty, 2017). Scientific validation of traditional knowledge would greatly impact healthcare as well as the conservation of cultures. Scientific research on the efficacy of these plants could lead to the development of scientifically supported natural therapies that could, in tandem, be used alongside the conventional drugs prescribed for diabetes (Modak *et al*., 2007). Besides, incorporating indigenous knowledge into traditional medical disciplines may also offer culturally responsive health care, especially in resource-poor settings where access to modern medical care can be challenging. The experimental aspect of this study which resulted in the determination of GI for certain plant species within the rat model, also supports the ethnobotanical findings. The glycemic index is a tool that has proven to be an integral part of diabetes treatment, as foods and plant sources with low GI cause a slow rise in blood glucose levels, thereby reducing the risk of postprandial hyperglycemia (Jenkins *et al*., 2002). *Dioscorea villosa*, commonly known as wild yam, is composed of bioactive constituents such as diosgenin that have been reported to affect glucose metabolism and increase insulin sensitivity (Wang *et al*., 2023). This finding aligns with the traditional use of *Dioscorea* species in many cultures for diabetes and other metabolic disorders (Obidiegwu *et al*., 2020). *Tinospora cordifolia*, another plant that showed promising results in the GI study, is a well-known adaptogen with anti-inflammatory and insulin-sensitizing effects (Grover *et al*., 2002). Its use in traditional medicine as a “universal healer” suggests its wide applicability for managing not only diabetes but also other chronic conditions such as arthritis and cardiovascular diseases (Upadhyay, 2023). *Trigonella foenum graecum*, also known as fenugreek, is a plant of significant ethnobotanical importance and has been shown to have mild activity in lowering blood glucose levels. *Fenugreek* seeds are rich in soluble fibre, which slows carbohydrate absorption, leading to a gradual rise in blood glucose levels (Hannan *et al*., 2007).

The saponins, alkaloids, and 4-hydroxyisoleucine present in fenugreek enhance its hypoglycemic activity through the stimulation of insulin release from pancreatic beta cells (Limaki, 2014). Integration of these experimental results with survey data provides a holistic view of the potential role of traditional plants in diabetes management. Findings from the study suggest that these plants may be useful for attenuating blood glucose levels and thereby preventing diabetes in prediabetic subjects, establishing their importance for both therapeutic and preventive uses (Furman *et al*., 2020). These findings have important public health implications, especially in a region like Assam, where health care infrastructure may be less well developed in rural areas. Promoting traditional plants as part of a more holistic approach to diabetes management may be an affordable and accessible alternative for people living in such communities. Moreover, their low side-effect profiles and societal acceptance make them suitable candidates for incorporation into local healthcare systems. However, further studies should be dedicated to the intensive pharmacological profiling of these plant materials, including the extraction of bioactive constituents and their mechanisms of action. Furthermore, conducting human studies to assess the efficacy and safety of these plants in real-world settings is also important. In addition, the long-term effects of these plants on glycemic control, insulin sensitivity, and overall metabolic health should also be identified.

Conclusion

The present study highlights the valuable role of traditional plants in the management of diabetes in Assam. In Assam, districts like Kamrup, Sivasagar, and Nalbari have reported high numbers of diabetic patients. Kamrup district leads with the most cases, followed by Sivasagar. The combined ethnobotanical survey and glycemic index studies provide strong evidence supporting the use of plants such as *T.cordifolia* and *D.villosa* as effective natural therapies for controlling blood glucose levels. The integration of traditional knowledge into modern healthcare frameworks could offer sustainable solutions for managing diabetes, particularly in resource-poor settings, while also preserving the rich cultural heritage of indigenous medicinal practices.

Supplementary information

The author(s) is responsible for the content or functionality of any supplementary information. Any queries regarding the same should be directed to the corresponding author. The supplementary information is available for download from the article's webpage and will not be included in the print copy.

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Conflict of interest

The authors declare that they have no conflict of interest.

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