Ethnobotanical study of traditional antidiabetic plants with potential synergistic use with modern formulations in coastal Odisha, India

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Research

Abstract

Background: Diabetes mellitus is a growing global health challenge, particularly in under-resourced coastal and rural regions where conventional healthcare access is limited. In these settings, communities often rely on traditional medicinal knowledge and locally available plants for managing diseases, including diabetes.

Methods: An ethnobotanical survey was conducted over nine months (February-October 2023) in the coastal districts of Odisha, specifically in Balasore and Bhadrak. A total of 105 informants—including traditional healers, farmers, fisherfolk, and women-led self-help group members-were interviewed using semi-structured questionnaires, free listing, and field walks. Data were analyzed using key ethnobotanical indices such as Relative Frequency of Citation (RFC), Cultural Importance Index (CI), and Use Reports per Participant (UR/N).

Results: Fifty medicinal plant species traditionally used for diabetes were documented. *Terminalia pallida* (RFC: 0.99, CI: 1.14, UR: 120) and *Didymocarpus pedicellata* (RFC: 0.99, CI: 1.10, UR: 115) were the most culturally and therapeutically valued species. Twenty-six polyherbal formulations were identified, with combinations like *D. pedicellata* + *T. pallida* (RFC: 0.99, CI: 1.05) and *Syzygium cumini* + *Phyllanthus emblica* (RFC: 0.97, CI: 0.91) rated as highly effective. These plant pairs are believed to exert synergistic effects on glycemic regulation and organ protection.

Conclusions: The study highlights a rich, community-driven pharmacopoeia of antidiabetic plants, many of which influence key metabolic pathways such as AMP-activated Protein Kinase activation and oxidative stress modulation. These findings support further pharmacological validation of high-ranking species and their combinations. Traditional knowledge, when documented systematically, can guide the development of accessible, integrative antidiabetic therapies rooted in cultural and ecological sustainability.

Keywords: Ethnobotany; Diabetes mellitus; Polyherbal formulation; Traditional medicine; Odisha; Synergistic phytotherapy

Background

Diabetes mellitus is a chronic metabolic condition characterised by elevated blood glucose levels resulting from insufficient insulin production, reduced insulin sensitivity, or both. It is a leading cause of mortality and morbidity across the world, with serious complications including cardiovascular disease, renal failure, neuropathy, and retinopathy (Jain *et al*., 2025). India is among the countries most affected by this epidemic, where the burden of type 2 diabetes is increasing rapidly. While urban areas experience fast lifestyle transitions that promote obesity and insulin resistance, rural and coastal regions are challenged by limited access to consistent medical infrastructure and affordable long-term therapies (Nnadiukwu *et al*., 2024).

In this backdrop, communities in many parts of India still rely on traditional healing systems and locally available medicinal plants to manage chronic diseases like diabetes. Traditional medicine in India comprises systems such as Ayurveda, Siddha, Unani, and various tribal and folk practices (Jain *et al*., 2025). In these systems, plant-based therapies are central, and many natural substances have long been employed to regulate blood sugar and treat symptoms associated with diabetes. The value of this indigenous knowledge, much of which is orally transmitted, remains immense but under-documented. One of the most prominent strategies in traditional medicine is the use of polyherbal formulations, which combine multiple plant species in a single therapeutic preparation (Dellaoui *et al*., 2025; Kondalkar *et al*., 2025).

The logic behind polyherbal therapy is rooted in the principle of synergy, where the combined effect of two or more medicinal plants is greater than the sum of their individual effects. Plants often possess multiple phytochemicals such as alkaloids, flavonoids, tannins, glycosides, and terpenoids that can act on diverse metabolic targets (Rath *et al*., 2024). When combined, these bioactive constituents may enhance absorption, increase receptor binding, modulate enzyme activity, or protect against oxidative damage more efficiently than isolated compounds. Polyherbal formulations are also believed to reduce side effects by balancing opposing properties of individual components (Roy 2025).

From a molecular standpoint, many plant-derived compounds influence key pathways related to glucose metabolism. For example, flavonoids and phenolic acids found in plants like *Syzygium cumini (*Rosa *et al*., 2024), *Phyllanthus emblica (*Singh *et al*., 2024), and *Didymocarpus pedicellate* (Hartanti *et al*., 2025) have been shown to modulate enzymes like alpha-glucosidase, alpha-amylase, and DPP-4, which control postprandial glucose levels. Others, such as triterpenoids and steroids, may enhance GLUT4 translocation, promoting glucose uptake into cells. Additionally, several herbal constituents activate the AMP-activated protein kinase (AMPK) pathway, a master regulator of cellular energy homeostasis that is often impaired in diabetic individuals. Many polyphenols also inhibit protein tyrosine phosphatase 1B (PTP1B), thereby improving insulin receptor sensitivity and downstream signalling (Asliddin & Gulnaz, 2025).

The role of traditional healers in preserving and transmitting this knowledge is indispensable. In coastal regions such as Odisha, traditional herbalists and community elders are often the first point of contact for individuals suffering from chronic conditions like diabetes (Nazar *et al*., 2024). Their therapeutic practices are based on a deep understanding of locally available flora, ecological cycles, and human physiology as interpreted through ancestral wisdom. These healers not only prepare medicines but also guide dietary patterns, seasonal cleansing practices, and the appropriate use of herbs based on an individual's constitution or imbalance (Bhattacharya *et al*., 2024). Odisha, located on the eastern coast of India, is home to a rich tapestry of cultural and medicinal plant traditions. The coastal belt, covering districts such as Ganjam, Puri, Kendrapara, Jagatsinghpur, and Balasore, supports ecosystems ranging from sandy beaches and mangroves to moist deciduous forests and sacred groves. Local communities in these areas—including fisherfolk, coastal cultivators, women-led self-help groups, and herbal vendors—use a variety of plants to prepare home remedies for diabetes (Ralte *et al*., 2024). These include decoctions, pastes, powders, and fermented extracts derived from fruits, roots, leaves, seeds, and bark. While some plants like *Momordica charantia* (bitter gourd) and *Gymnema sylvestre* (Gudmar) are widely recognized, others like *Didymocarpus pedicellata* and *Terminalia pallida* remain largely unknown to the scientific community, despite their consistent use in local formulations (Jain *et al*., 2025).

Despite the widespread use of these plant combinations, there is limited scientific validation of their synergistic effects, especially in real-world polyherbal preparations. Very few studies have explored how these formulations act at cellular and systemic levels, how they influence existing pharmacotherapies, or how they vary across different cultural contexts (Frimpong *et al*., 2024). The therapeutic success of many of these polyherbal combinations is deeply rooted in collective experience and empirical observation, often refined over generations of trial and error. Ethnobotanical research is a powerful approach to document this traditional wisdom and assess its relevance in modern health challenges (Priyanka *et al*., 2024). By systematically recording the identity of antidiabetic plants, their parts used, methods of preparation, dosage, perceived

efficacy, and source of knowledge, ethnobotanical surveys help preserve disappearing knowledge systems. Additionally, through tools like relative frequency of citation (RFC) and cultural importance index (CI), researchers can identify the most valued species and combinations, thus prioritizing them for pharmacological testing (Ajao & Sadgrove, 2024).
In this context, the present study was designed to explore and document the traditional knowledge related to the use of medicinal plants for the management of diabetes in the coastal belt of Odisha. The primary objective was to carry out an ethnobotanical survey to identify plant species that are commonly used by local communities for controlling blood sugar levels. The study also aimed to gather information on the parts of the plant used, methods of preparation, routes of administration, and the traditional names associated with these plants. In addition, the research intended to understand how this knowledge is transmitted across generations and how different social and occupational groups perceive the effectiveness of these remedies. Another important focus of the study was to identify and compile plant combinations used in traditional practices and to propose a set of potential polyherbal formulations that reflect community-based usage. Through this approach, the study seeks to lay a cultural and scientific foundation for future research that can validate and develop antidiabetic remedies inspired by traditional practices.

Materials and Methods

Study area

The present study was conducted in the coastal plains of northern Odisha, focusing on selected areas of Balasore and Bhadrak districts. These regions lie between 21.3-21.9°N latitude and 86.6-87.3°E longitude, forming a transitional ecological zone between the Bay of Bengal and the inland alluvial plains. The landscape includes sandy coasts, tidal wetlands, estuaries, mangrove patches, and riverine floodplains (Behera *et al*., 2025).

Major rivers such as the Subarnarekha, Baitarani, and Salandi enrich the region's biodiversity and agricultural productivity. The area experiences a humid tropical monsoon climate, receiving 1400-1600 mm of annual rainfall mainly from June to September. Temperatures range from about 10°C in winter to above 40°C in summer. High humidity and saline winds create unique microclimates that shape local vegetation and cropping systems.

Soil types vary from sandy loam near the coast to fertile alluvial soils inland (Sahoo & Bhoi, 2025). The flora includes tropical deciduous trees, medicinal herbs, coastal shrubs, and mangrove associates, all supporting a wide range of traditional healing practices. Interior villages preserve ancient ecological traditions and are inhabited by tribal and non-tribal communities who depend heavily on herbal medicine.

The coastal region has a rich maritime history dating back to ancient Kalinga, with trade links to Southeast Asia. These interactions contributed to the blending of indigenous and foreign ethnobotanical knowledge, making the region an important site for studying cultural adaptation and traditional medical practices (Bhoi & Ahirwar, 2025). Figure 1 shows the map of the study area.

Tribal Profile of the Study Region

Tribal communities form a major part of the rural population in the study area. According to recent census data, about 29% of people in selected blocks of Balasore and Bhadrak belong to the Scheduled Tribes. The major groups include the Bathudi, Santal, Lodha, Kolha, Bhuyan, and Mankidia communities.

These groups inhabit forest-fringed and coastal villages and possess extensive knowledge of local ecosystems. The Bathudi and Santal are primarily agricultural, while the Lodha and Mankidia depend more on forest-based livelihoods. Languages such as Odia, Santali, and tribal dialects are used interchangeably. Literacy rates among the tribal population range from 45-65%, and herbal healing remains widely practiced through oral traditions (Sahu & Mahalik, 2024; Jena & Devi, 2024).

Field Study

The ethnobotanical survey was conducted over a period of nine months, from February to October 2023, covering five administrative blocks: Remuna and Nilagiri in Balasore district, and Basudevpur, Dhamnagar, and Chandbali in Bhadrak district, by adopting the literature of Aumeeruddy & Mahomoodally,2020. The sites were chosen to represent ecological variation, tribal diversity, accessibility, and the willingness of the local communities to participate. A total of 105 participants were recruited using a purposive sampling approach, focusing on individuals recognized within their communities for their expertise in traditional medicinal plant knowledge. The participants included tribal elders, folk healers, coastal herbalists, experienced users of plant-based remedies, fisherfolk, crop cultivators, women from self-help groups, and local herbal vendors. Efforts were made to ensure a balanced representation across age, gender, and social roles to enhance the inclusiveness and credibility of the data collected.

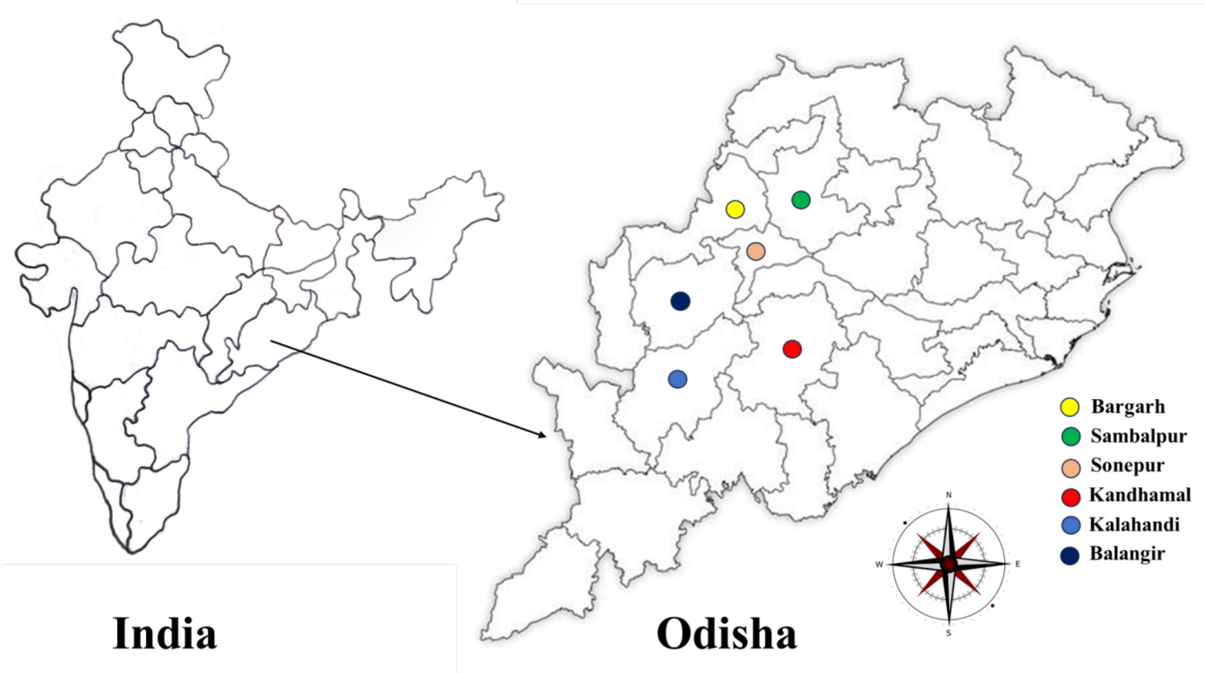


Figure 1. Map of the study area

Communication of Concepts and Interview Procedure

Since biomedical concepts such as diabetes and blood sugar control do not always translate directly into local languages, these concepts were carefully communicated in Odia and Santali through culturally relevant descriptions of associated symptoms, including frequent urination, excessive thirst, weight loss, and fatigue. Preliminary consultations with local health workers and translators helped identify appropriate terms and expressions that participants could readily understand. Data collection was carried out using semi-structured interviews, free listing, and guided field walks, during which participants were asked to describe the plants they use for symptoms corresponding to diabetes, the specific parts of the plants utilized, methods of preparation and administration, whether plants are used alone or in combinations, observed therapeutic effects, and the mode of knowledge transmission, including family, apprenticeship, or community sharing. All interviews were conducted with prior informed consent, audio-recorded when permitted, and supplemented by detailed field notes to capture contextual observations and nuances of plant use (Acharya *et al*., 2023).

Taxonomic Identification of Plant Specimens

Plant specimens reported by participants were systematically collected and preserved as voucher specimens to ensure accurate documentation. Detailed photographs of leaves, flowers, and fruits were taken to support morphological identification. Preliminary identification was performed using regional floras and relevant ethnobotanical literature, while final verification of scientific names was carried out through authoritative online databases, including Plants of the World Online (https://powo.science.kew.org) and the International Plant Name Index (https://www.ipni.org). All verified specimens were deposited at the Herbarium Unit, Department of Botany, Fakir Mohan University, Balasore, Odisha, providing a permanent reference for future research. This methodological framework incorporated ecological, cultural, and linguistic diversity, thereby enhancing the scientific rigor, reproducibility, and long-term value of the ethnobotanical study.

Knowledge Documentation, Coding, and Analysis

To evaluate the ethnobotanical data collected on traditionally used antidiabetic plants, we employed several quantitative indices that help measure the significance and cultural relevance of each species. One of the key tools used was the Use Value (UV), which quantifies how frequently a particular plant is mentioned by informants in relation to its therapeutic applications. This index offers insight into the prominence of each species within the community's traditional knowledge system. The UV was calculated by dividing the total number of use reports for each plant by the number of informants participating in the study, thus indicating both the popularity and versatility of the plant in managing diabetes. This method helps identify plants that are not only widely recognized but also potentially involved in synergistic interactions within polyherbal formulations (Sharma *et al*., 2025).

$$UV = \frac{\sum U}{N}$$

Where, ∑U denotes the total number of use reports for a given species, and N represents the total number of informants interviewed. This index helps in highlighting plants that are widely recognized and used in multiple contexts, indicating their versatility and embeddedness in local health practices.
We recorded the Use Report (UR) as the aggregate number of times a particular plant species was mentioned by informants for its therapeutic applications, reflecting its overall prominence within the community. To evaluate the level of agreement among informants about the medicinal relevance of specific plants, we also calculated the Relative Frequency of Citation (RFC), which serves as an indicator of shared traditional knowledge. The RFC was determined using the following formula:

$$RFC = \frac{FC}{N}$$

Where, FC represents the number of informants who cited the species, and N is the total number of informants interviewed.
We employed the Cultural Importance Index (CI) to assess the overall ethnobotanical relevance of each plant species by accounting for both the number of informants citing a species and the diversity of its reported uses across different therapeutic contexts. This metric provided a broader perspective on how individual plant species are integrated into the community's traditional healthcare practices. The CI was calculated using the formula (Ogwu *et al*., 2025)

$$CI = \sum_{j=1}^{n} \left(\mathrm{n} \frac{URij}{N} \right)$$

Where, UR represents the number of use-reports for each use category and N is the total number of informants. This approach enabled us to identify species that hold not only therapeutic value but also a culturally embedded role in local medical traditions.

Results

Demographic Information of the Participants

A total of 105 participants were interviewed during the study. The highest number of respondents came from Gopalpur (14.29%), followed by Puri (13.33%), Paradip (12.38%), and Chandipur (11.43%). Other sites such as Konark, Talsari, Astaranga, Pentha (Kendrapara), and Devi River Mouth (Jagatsinghpur) contributed nearly equally to the remainder.

Gender distribution was nearly balanced, with males comprising 51.43% and females 48.57% of the sample. Fisherfolk, including small-scale boat owners and helpers, represented the largest occupational group (24.76%). This was followed by women's self-help group members involved in herbal product sales, dried fish, or handicrafts (21.90%), traditional healers (20.00%), coastal farmers (18.10%), and herbal vendors (15.24%).

The majority of participants were aged 60-80 years (37.14%), indicating a predominance of elderly knowledge holders. Other age groups included 40-60 years (27.62%), below 40 years (22.86%), and above 80 years (12.38%). Educational levels varied, with most having primary education (30.48%), followed by secondary (26.67%), no formal education (23.81%), and college-level education (19.05%). Table 1 summarizes the socio-demographic characteristics of participants.

Table 1. Socio-Demographic Profile of Study Participants

Socio-Demographic Variables	**Parameters**	**Sample Number**	**Percentage (%)**
Locality	Gopalpur	15	14.29
	Puri	14	13.33
	Paradip	13	12.38
	Chandipur	12	11.43
	Talsari	10	9.52

	Astaranga	10	9.52
	Konark	11	10.48
	Pentha (Kendrapara)	10	9.52
	Devi River Mouth (Jagatsinghpur district)	10	9.52
Gender	Male	54	51.43
	Female	51	48.57
Occupation	Traditional herbal practitioners	21	20.00
	Fisherfolk (including small-scale boat owners and helpers)	26	24.76
	Coconut/cashew cultivators and coastal farmers	19	18.10
	Women SHG members (selling forest/herbal products, dried fish, or handicrafts)	23	21.90
	Local herbal vendors / plant sellers (fresh or dried)	16	15.24
Age Group	Below 40 years	24	22.86
	40-60 years	29	27.62
	60-80 years	39	37.14
	Above 80 years	13	12.38
Education Level	No formal education	25	23.81
	Primary education	32	30.48
	Secondary / High school	28	26.67
	Vocational / College-level	20	19.05

Most Utilised Plants in Traditional Antidiabetic Formulations

The survey documented 50 medicinal plant species belonging to diverse families, with most collected from wild habitats. Commonly used parts included leaves, fruits, roots, bark, stems, and occasionally whole plants, with leaves being dominant. Seasonal availability ranged mainly from August to February, although species like *Tinospora cordifolia*, *Murraya koenigii*, and *Aloe vera* were accessible year-round.

Most plants were gathered from forests, riverbanks, and roadside groves, while some were cultivated in home gardens. Decoctions and powders were the most common preparation forms, followed by juices, infusions, and pastes, reflecting the simplicity of indigenous methods.

Manual collection methods such as plucking, root digging, bark scraping, and stem cutting were widely practiced. Species like *Gymnema sylvestre*, *Momordica charantia*, *Syzygium cumini*, *Tinospora cordifolia*, *Terminalia chebula*, *Didymocarpus pedicellata*, and *Terminalia pallida* were recorded with voucher specimens and appeared central to traditional diabetic treatment systems. Table 2 provides a detailed list of the 50 species documented.

High-Consensus Antidiabetic Plants Based on Multi-Index Evaluation

Quantitative analysis identified the top ten antidiabetic plants using indices such as Informant Citations (IP), Informant Responses (IR), Use Reports (UR), Relative Frequency of Citation (RFC), and Cultural Importance Index (CI). *Terminalia pallida* ranked highest with 104 citations, 100 responses, and 120 use reports, yielding an RFC of 0.99 and CI of 1.14. This indicates its dominant therapeutic role and broad cultural acceptance.

Didymocarpus pedicellata followed closely (CI = 1.10), valued for nephroprotective and glucose-lowering properties. *Phyllanthus emblica* ranked next, known for its antioxidant and glucose-modulating effects. *Desmodium gangeticum* (RFC = 0.91; CI = 1.06) was commonly cited for immunomodulatory and hepatic support in diabetes management.

Other top species included *Pterocarpus marsupium*, *Momordica charantia*, *Andrographis paniculata*, *Tinospora cordifolia*, *Aegle marmelos*, and *Syzygium cumini*, all recognized for enhancing insulin sensitivity, reducing oxidative stress, and supporting liver function. Table 3 summarizes the quantitative indices of all 50 species.

Table 2. Ethnobotanical Details of Antidiabetic Plant Species Documented in Coastal Odisha

Species Name	Family	Local Name	Season Available	Voucher Specimen No.	Habitat	Part Used	Consumable Form	Collection Method	Nature (Wild/Cultivated)
Andrographis paniculata (Burm.f.) Nees	Acanthaceae	Kalmegha	Sept-Dec	OUH-008	Marshy lands	Whole plant	Juice, dried powder	Whole plant pull	Wild
Justicia adhatoda L.	Acanthaceae	Basanga	Oct-Feb	OUH-017	Village boundary hedges	Leaves	Juice, paste	Leaf plucking	Wild/Cultivated
Achyranthes aspera L.	Amaranthaceae	Apamaranga	Aug-Nov	OUH-049	Forest margins	Root, seed	Powder, decoction	Hand-harvested	Wild
Mangifera indica L.	Anacardiaceae	Amba	May-July	OUH-027	Homesteads	Leaves	Juice, decoction	Leaf hand-picking	Cultivated
Calotropis gigantea (L.) W.T.Aiton	Apocynaceae	Arakh	Year-round	OUH-046	Dry open fields	Leaf, root	Paste, latex extract	Cautious plucking	Wild
Gymnema sylvestre R.Br.	Apocynaceae	Gudmar	Oct-Jan	OUH-001	Forest edges	Leaves	Decoction, powder	Manual plucking	Wild
Holarrhena pubescens Wall. ex G.Don	Apocynaceae	Kureya	May-Sept	OUH-015	Forest clearings	Bark, seed	Decoction, powder	Bark stripping	Wild
Aloe vera (L.) Burm.f.	Asphodelaceae	Ghrutakumari	Year-round	OUH-031	Garden patches	Leaf gel	Juice, raw gel	Leaf cutting	Cultivated
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	Combretaceae	Arjuna	Nov-Mar	OUH-044	Riverbanks, forest edge	Bark	Powder, decoction	Bark scraping	Wild
Terminalia bellirica (Gaertn.) Roxb.	Combretaceae	Bahada	Nov-Feb	OUH-039	Dry deciduous forests	Fruit	Powder, decoction	Fruit collection	Wild
Terminalia chebula Retz.	Combretaceae	Harida	Oct-Jan	OUH-007	Dry deciduous forest	Fruit	Powder, infusion	Collected when dry	Wild
Terminalia pallida Brandis	Combretaceae	Asan Harida	Nov-Feb	OUH-012	Hill slopes, dry groves	Fruit	Powder, decoction	Fruit collection	Wild/Semi-cultivated
Costus speciosus (J.Koenig) Sm.	Costaceae	Keu kandha	July-Oct	OUH-040	Moist slopes, streamsides	Rhizome	Paste, infusion	Rhizome digging	Wild
Coccinia grandis (L.) Voigt	Cucurbitaceae	Kunduri	May-Sept	OUH-003	Field margins	Leaves, fruit	Curry, raw, decoction	Handpicked	Semi-cultivated
Momordica charantia L.	Cucurbitaceae	Karala / Kalara	Aug-Nov	OUH-002	Home gardens	Fruit	Juice, cooked veg	Knife-cutting	Cultivated
Dillenia indica L.	Dilleniaceae	Oau / Oulu	Aug-Nov	OUH-016	Moist forest margin	Fruit	Raw, juice	Fruit handpicked	Wild/Sacred groves
Bauhinia variegata L.	Fabaceae	Kanchan Tree	Feb-Apr	OUH-026	Roadsides	Bark, flowers	Decoction	Bark stripping	Semi-cultivated

Cajanus scarabaeoides (L.) Thouars	Fabaceae	Banar Harada	Sept-Nov	OUH-021	Open grassland	Seeds	Powder, infusion	Pod collection	Wild
Cassia auriculata L.	Fabaceae	Chinnapendi	Aug-Oct	OUH-010	Roadside slopes	Flowers, bark	Decoction	Flower plucking	Wild
Cassia occidentalis L.	Fabaceae	Kasundhi	Aug-Oct	OUH-042	Roadside wasteland	Leaf	Decoction, paste	Leaf collection	Wild
Clitoria ternatea L.	Fabaceae	Aparajita	Sept-Dec	OUH-050	Garden hedges	Root, flower	Tea, decoction	Flower/root collection	Cultivated
Desmodium gangeticum (L.) DC.	Fabaceae	Salaparni	July-Oct	OUH-013	Lateritic soils	Root	Decoction	Root digging	Wild
Pongamia pinnata (L.) Pierre	Fabaceae	Karanja	Oct-Jan	OUH-043	Riverbanks	Seed, leaf	Oil, decoction	Seed collection	Wild
Pterocarpus marsupium Roxb.	Fabaceae	Bijasal	Nov-Feb	OUH-022	Moist deciduous forest	Heartwood	Soaked extract	Bark shaving	Wild
Trigonella foenum-graecum L.	Fabaceae	Methi	Nov-Feb	OUH-005	Cultivated land	Seeds, leaves	Powder, sprouts	Harvested with crop	Cultivated
Swertia chirata (Roxb. ex Fleming) Karsten	Gentianaceae	Chiraita	Aug-Nov	OUH-025	Hill slopes	Whole plant	Decoction, powder	Whole plant collection	Wild (seasonal)
Didymocarpus pedicellata R.Br.	Gesneriaceae	Patharkuchi	Sept-Dec	OUH-011	Moist rocky slopes	Leaves	Juice, decoction	Leaf plucking	Wild
Clerodendrum indicum (L.) Kuntze	Lamiaceae	Bhuin Neem	Aug-Nov	OUH-014	Roadside hedges	Leaves, root	Paste, juice	Root and leaf handpick	Wild
Ocimum gratissimum L.	Lamiaceae	Ram Tulasi	Year-round	OUH-023	Backyard gardens	Leaves	Juice, infusion	Leaf plucking	Cultivated
Vitex negundo L.	Lamiaceae	Nirgundi	Aug-Dec	OUH-045	Near ponds	Leaf	Infusion	Leaf handpicked	Wild
Lawsonia inermis L.	Lythraceae	Henna / Mehendi	Oct-Feb	OUH-032	Dry field borders	Leaves	Decoction, paste	Leaf plucking	Semi-wild
Abroma augusta L.	Malvaceae	Ulatkambal	Sept-Dec	OUH-029	Moist forest undergrowth	Bark, root	Decoction	Bark/root collection	Wild
Helicteres isora L.	Malvaceae	Marodphali	Oct-Feb	OUH-047	Dry deciduous groves	Fruit	Decoction, powder	Fruit plucked	Wild
Sida cordifolia L.	Malvaceae	Bala	July-Oct	OUH-035	Waste lands	Root, stem	Decoction	Root harvesting	Wild
Azadirachta indica A.Juss.	Meliaceae	Neem	Mar-June	OUH-041	Village roadsides	Leaf, bark	Juice, powder	Leaf plucking	Wild/Cultivated
Stephania japonica (Thunb.) Miers	Menispermaceae	Akani bela	June-Sept	OUH-037	Wetland boundaries	Root, stem	Paste, decoction	Stem/root collection	Wild
Tinospora cordifolia (Willd.) Miers	Menispermaceae	Guluchi	Year-round	OUH-006	Moist fence lines	Stem	Juice, decoction	Stem cutting	Wild/Semi-cultivated
Tinospora crispa (L.) Hook.f. & Thomson	Menispermaceae	Guluchi bela	Year-round	OUH-020	Climbing on fences	Stem	Decoction, juice	Stem cutting	Wild/Semi-domestic

Ficus racemosa L.	Moraceae	Dumur	May-Oct	OUH-024	Riverbanks, wetlands	Bark, fruit	Decoction, raw fruit	Bark scraping	Wild
Eugenia heyneana Wall.	Myrtaceae	Jamun gacha	May-July	OUH-018	Moist deciduous groves	Fruit, bark	Decoction, powder	Bark scraping	Wild
Syzygium cumini (L.) Skeels	Myrtaceae	Jamukoli	May-July	OUH-004	Roadside, groves	Seed, bark	Powder, decoction	Fruit collection + bark scraping	Wild
Boerhavia diffusa L.	Nyctaginaceae	Punarnava	Aug-Nov	OUH-034	Field margins	Whole plant	Decoction, paste	Entire plant pulled	Wild
Averrhoa carambola L.	Oxalidaceae	Kamrakh	June-Aug	OUH-030	Garden edges	Fruit	Raw, juice	Fruit picking	Cultivated
Phyllanthus emblica L.	Phyllanthaceae	Aonla	Nov-Jan	OUH-033	Sacred groves, groves	Fruit	Juice, raw, powder	Fruit plucking	Wild/Cultivated
Bacopa monnieri (L.) Wettst.	Plantaginaceae	Brahmi	July-Oct	OUH-048	Marshy areas	Whole plant	Fresh juice, paste	Entire plant pulled	Wild
Cymbopogon citratus (DC.) Stapf	Poaceae	Gandharaj ghasa	Year-round	OUH-036	Garden edges, plantations	Leaf	Infusion, tea	Leaf cutting	Cultivated
Aegle marmelos (L.) Corrêa	Rutaceae	Bela	May-Aug	OUH-009	Sacred groves	Fruit, leaf	Juice, raw pulp	Fruit picked	Wild/Cultivated
Murraya koenigii (L.) Spreng.	Rutaceae	Bhursunga Patra	Year-round	OUH-019	Homestead backyards	Leaves	Curry leaf, decoction	Leaf plucking	Cultivated
Lygodium flexuosum (L.) Sw.	Schizaeaceae	Bicha lata	Aug-Oct	OUH-038	Damp forest floor	Leaflets	Decoction	Handpicked	Wild
Zingiber officinale Roscoe	Zingiberaceae	Ada	Dec-Mar	OUH-028	Home gardens	Rhizome	Powder, infusion	Rhizome digging	Cultivated

Table 3. Quantitative Ethnobotanical Indices of Antidiabetic Plant Species Used in Coastal Odisha

Species Name	**IP (participant)**	**IR (response)**	**UR**	**RFC**	**CI**
Gymnema sylvestre R.Br.	98	90	101	0.93	0.96
Momordica charantia L.	96	85	108	0.91	1.03
Coccinia grandis (L.) Voigt	85	76	95	0.81	0.90
Syzygium cumini (L.) Skeels	100	99	89	0.95	0.85
Trigonella foenum-graecum L.	85	82	103	0.81	0.98
Tinospora cordifolia (Willd.) Miers	89	87	99	0.85	0.94
Terminalia chebula Retz.	84	80	85	0.80	0.81
Andrographis paniculata (Burm.f.) Nees	90	88	106	0.86	1.01
Aegle marmelos (L.) Corrêa	101	90	102	0.96	0.97
Cassia auriculata L.	83	75	90	0.79	0.86
Didymocarpus pedicellata R.Br.	104	102	115	0.99	1.10
Terminalia pallida Brandis	104	100	120	0.99	1.14
Desmodium gangeticum (L.) DC.	90	85	110	0.86	1.05
Clerodendrum indicum (L.) Kuntze	100	93	95	0.95	0.90
Holarrhena pubescens Wall. ex G.Don	99	93	100	0.94	0.95
Dillenia indica L.	86	80	98	0.82	0.93
Justicia adhatoda L.	84	79	105	0.80	1.00
Eugenia heyneana Wall.	85	78	96	0.81	0.91
Murraya koenigii (L.) Spreng.	78	74	86	0.74	0.82
Tinospora crispa (L.) Hook.f. & Thomson	71	69	106	0.68	1.01
Cajanus scarabaeoides (L.) Thouars	89	84	107	0.85	1.02
Pterocarpus marsupium Roxb.	94	90	110	0.90	1.05
Ocimum gratissimum L.	96	95	100	0.91	0.95
Ficus racemosa L.	89	80	94	0.85	0.90
Swertia chirata (Roxb. ex Fleming) Karsten	100	99	82	0.95	0.78
Bauhinia variegata L.	95	90	86	0.90	0.82
Mangifera indica L.	94	90	93	0.90	0.89
Zingiber officinale Roscoe	81	75	99	0.77	0.94
Abroma augusta L.	86	84	86	0.82	0.82

Averrhoa carambola L.	79	75	95	0.75	0.90
Aloe vera (L.) Burm.f.	92	88	98	0.88	0.93
Lawsonia inermis L.	101	86	86	0.96	0.82
Phyllanthus emblica L.	100	84	111	0.95	1.06
Boerhavia diffusa L.	102	99	100	0.97	0.95
Sida cordifolia L.	85	80	98	0.81	0.93
Cymbopogon citratus (DC.) Stapf	96	94	93	0.91	0.89
Stephania japonica (Thunb.) Miers	82	80	97	0.78	0.92
Lygodium flexuosum (L.) Sw.	84	79	86	0.80	0.82
Terminalia bellirica (Gaertn.) Roxb.	87	84	102	0.83	0.97
Costus speciosus (J.Koenig) Sm.	83	75	100	0.79	0.95
Azadirachta indica A.Juss.	85	79	97	0.81	0.92
Cassia occidentalis L.	89	79	90	0.85	0.86
Pongamia pinnata (L.) Pierre	95	88	84	0.90	0.80
Terminalia arjuna (Roxb. ex DC.) Wight & Arn.	92	90	95	0.88	0.90
Vitex negundo L.	94	86	85	0.90	0.81
Calotropis gigantea (L.) W.T.Aiton	101	88	99	0.96	0.94
Helicteres isora L.	88	85	70	0.84	0.67
Bacopa monnieri (L.) Wettst.	82	80	85	0.78	0.81
Achyranthes aspera L.	79	71	89	0.75	0.85
Clitoria ternatea L.	99	89	80	0.94	0.76

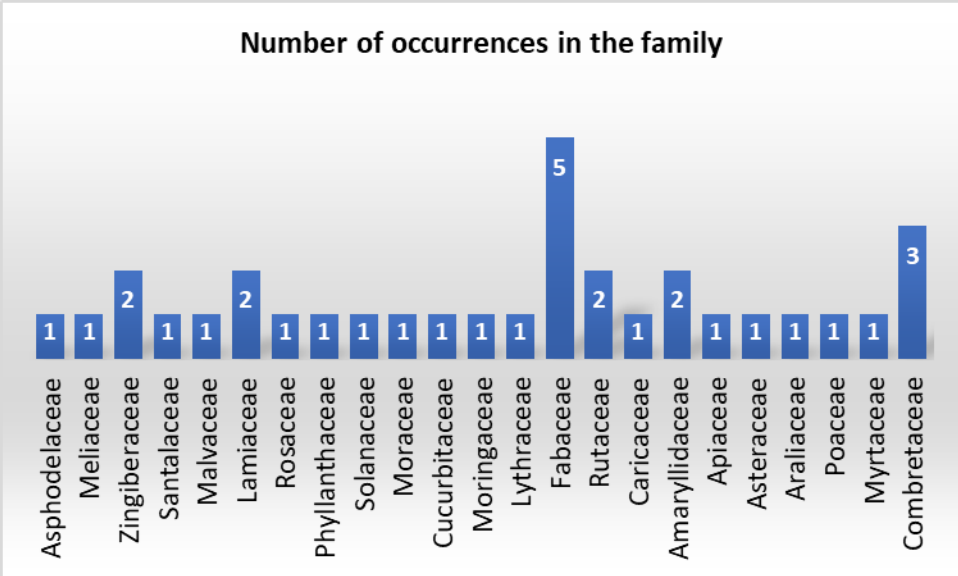
Comparative Analysis of Ethnobotanical Indices

Across all five indices—IP, IR, UR, RFC, and CI—certain plants consistently emerged as culturally and therapeutically dominant. *Terminalia pallida* topped the IP chart with 104 informants, followed by *Didymocarpus pedicellata*, *Phyllanthus emblica*, *Desmodium gangeticum*, and *Pterocarpus marsupium*.

The IR-based chart also placed *Terminalia pallida* first (100 responses), reaffirming its frequent use across formulations. In the UR analysis, *Terminalia pallida* again showed the highest number (120), followed closely by *Desmodium gangeticum* and *Phyllanthus emblica*, suggesting their use in treating both diabetes and related complications.

In the RFC comparison, *Terminalia pallida*, *Didymocarpus pedicellata*, *Phyllanthus emblica*, and *Desmodium gangeticum* all recorded values above 0.85, indicating strong community consensus. The CI chart confirmed *Terminalia pallida* (1.14) as the most culturally significant, followed by *Didymocarpus pedicellata* (1.10), *Desmodium gangeticum* (1.06), and *Phyllanthus emblica* (1.02). Figures 2-6 collectively illustrate the comparative ethnobotanical significance of the top ten antidiabetic plant species across different evaluation indices. Figure 2 shows the ten most frequently mentioned species based on Informant Participation (IP), highlighting the plants most commonly cited by respondents. Figure 3 presents the same species ranked according to Informant Responses (IR), reflecting the diversity of their reported uses. Figure 4 depicts the top ten plants with the highest number of Use Reports (UR), emphasizing their broad therapeutic application in traditional diabetic care. Figure 5 ranks these species by Relative Frequency of Citation (RFC), indicating the level of community consensus regarding their efficacy. Finally, Figure 6 displays the ranking based on the Cultural Importance Index (CI), integrating both frequency and diversity of use to reveal the most culturally and therapeutically valued plants in the study. Together, these findings reveal deep-rooted cultural trust and empirical understanding of plant synergy, forming a foundation for pharmacological validation and future phytomedicine development.

Figure 2. Pictorial representation of an ethnobotanical survey conducted in a specific area**:** [A] Collection of plant specimens of the sample *Curcuma longa* for the herbarium. [B] Visit a specific area where *Withania somnifera* and *Glycyrrhiza glabra* were harvested at the study location. [C] Collection of data from informants in the study area. [D] A field visit to the garden where *Allium cepa* and *Allium sativum* were harvested.



Fiure.3. Distribution of distinct families amongst plant specimens from the ethnobotanical survey

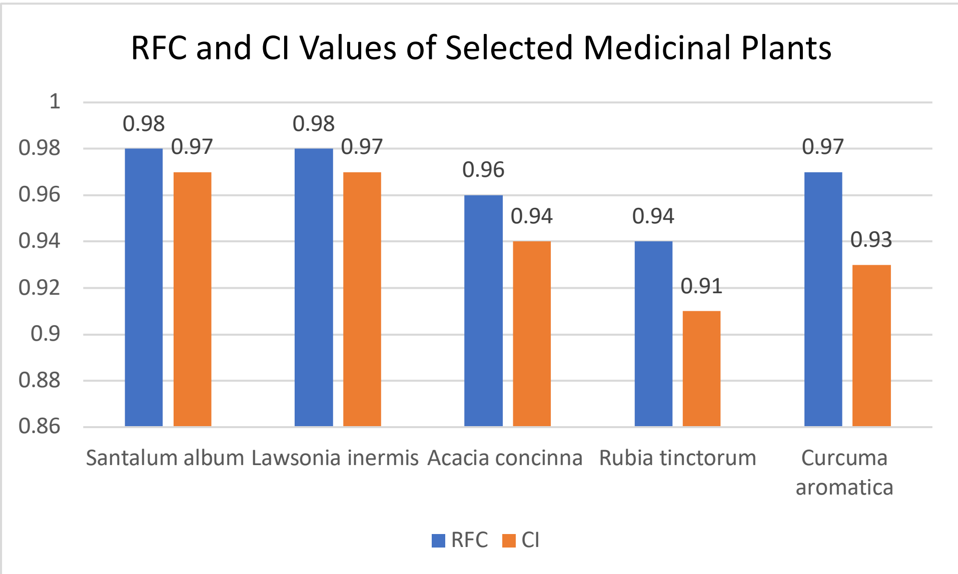


Figure 4. Representation of plant species above 0.9 RFC & CI

Traditional Polyherbal Ayurvedic Formulations for Diabetes Management

A total of 26 traditional Ayurvedic formulations used for diabetes management were recorded. These included combinations of plants with hypoglycemic, hepatoprotective, and immunomodulatory effects. Frequently occurring species included *Momordica charantia*, *Syzygium cumini*, *Gymnema sylvestre*, *Terminalia chebula*, *Andrographis paniculata*, and *Boerhavia diffusa*.

Formulations such as Nidigdhadi Vati and Karela Shunti Vati feature *Momordica charantia*, while *Syzygium cumini* appears in Jamunavaleha and Jambupatra Kashaya. *Gymnema sylvestre*, known for regenerating pancreatic β-cells, is a key component in Gudmarishta and Madhunashini Leha.

Dosage forms varied, including tablets, decoctions, fermented liquids, herbal jams, and medicated oils. Common adjuvants such as honey, ghee, and Trikatu churna were used to enhance absorption and palatability. Most formulations were administered before meals or at bedtime for optimal glycemic control. Table 4 lists all recorded formulations with preparation type, timing, and dosage.

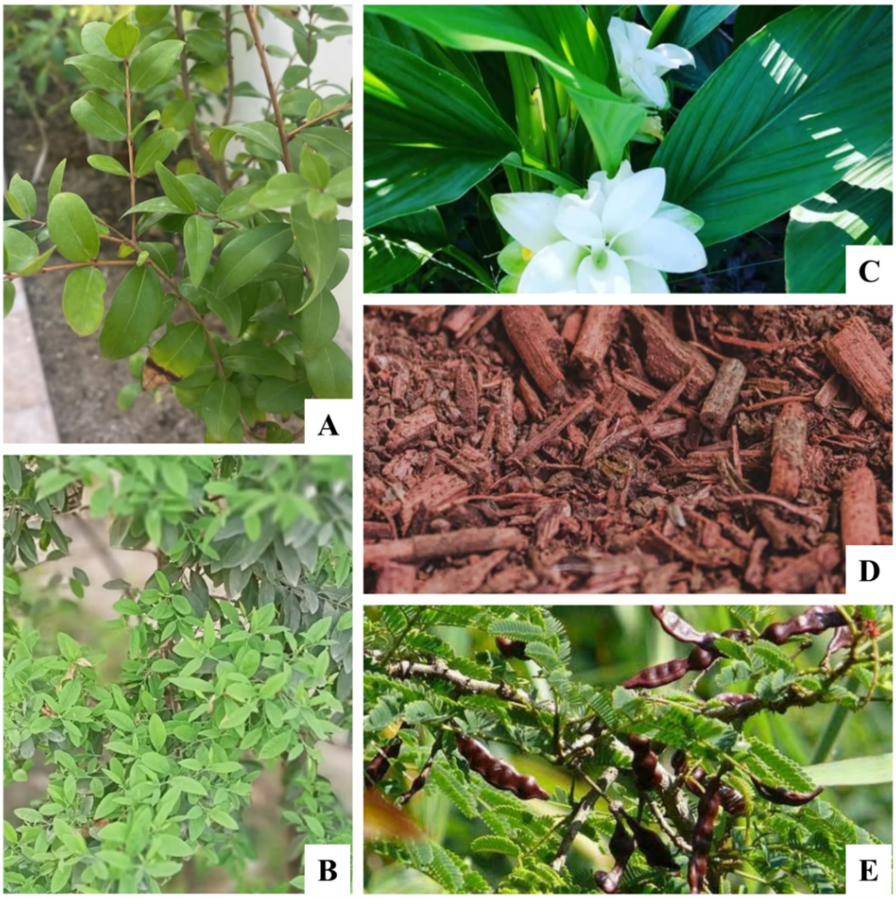


Figure 5. Collection of photographs of plant specimens whose RFC and CI are more than 0.90. [A] *Lawsonia inermis*, [B] *Santalum album*,[C]*Curcuma aromatica*[D]*Rubia tinctorum* ,[E]*Acacia concinna*

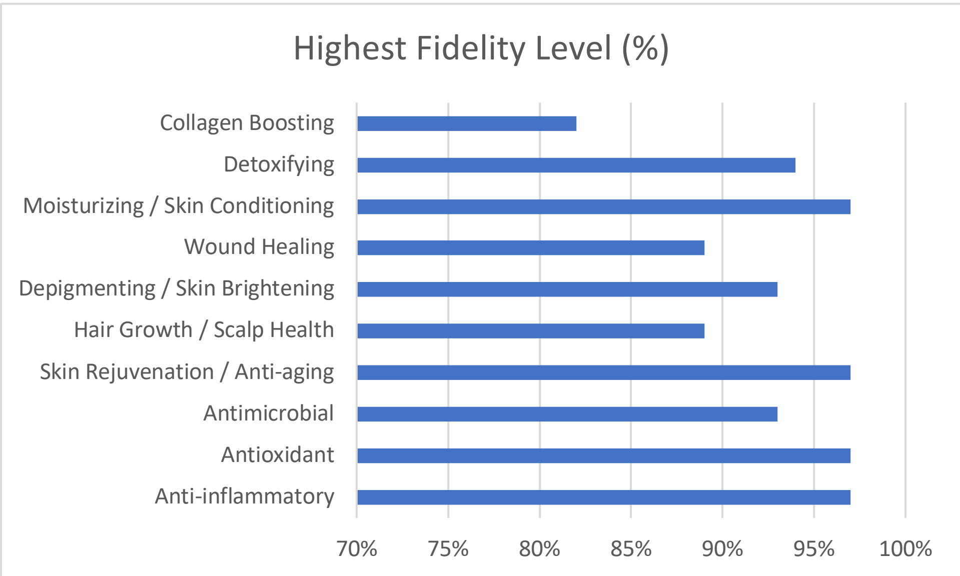


Figure. 6: Representation of the plant species with the highest percentile in each pharmacological effect.

Table 4. Traditional Antidiabetic Polyherbal Formulations Documented from Coastal Odisha

S.No	Formulation Name	Main Plant Ingredients	Vehicle	Additional Ingredients	Time of Consumption	Dose (per day)
1	Nidigdhadi Vati	*Momordica charantia, Syzygium cumini*	Tablet (dry)	Trikatu churna	Before breakfast	1-2 tablets
2	Chitradya Kashayam	*Andrographis paniculata, Aegle marmelos, Ficus racemosa*	Water decoction	Ginger slices	Before lunch	50 ml
3	Jamunavaleha	*Syzygium cumini, Phyllanthus emblica*	Sugar-free paste	Honey, ghee	Night (post dinner)	1-2 tsp
4	Triphala Madhughna Ras	*Terminalia chebula, T. bellirica, P. emblica*	Hot water	Black pepper	Early morning	30 ml
5	Madhumeharishtam	*Didymocarpus pedicellata, Terminalia pallida*	Fermented decoction	Jaggery, *Piper longum*	After meals	15-20 ml
6	Karela Shunti Vati	*Momordica charantia, Zingiber officinale*	Dry tablet	Rock salt	Before food	1 tablet
7	Gudmarishta	*Gymnema sylvestre, Ocimum gratissimum, Cassia auriculata*	Self-fermented decoction	Raisins	After meals	20 ml
8	Panarnava Vati	*Boerhavia diffusa, Tinospora cordifolia*	Compressed tablet	Gum acacia	Before breakfast	1-2 tablets
9	Karpuradi Kashayam	*Mangifera indica, Cajanus scarabaeoides, Swertia chirata*	Water decoction	Clove powder	Before lunch	40 ml
10	Kanchnaradi Arka	*Bauhinia variegata, Lawsonia inermis*	Distilled liquid	Camphor essence	Mid-morning	10-15 drops
11	Madhunashini Leha	*Gymnema sylvestre, Abroma augusta*	Herbal jam	Cow ghee, jaggery	Before bed	1 tsp
12	Trinetradi Vati	*Cassia occidentalis, Azadirachta indica, Vitex negundo*	Tablet	Long pepper, dried ginger	After lunch	2 tablets
13	Arjunadi Rasayana	*Terminalia arjuna, Helicteres isora*	Ghee-based	Licorice, rock sugar	Morning empty stomach	5 gm
14	Amrutaphaladi Syrup	*Averrhoa carambola, Murraya koenigii*	Syrup	Cardamom, lemon juice	After meals	10 ml
15	Tiktaka Kashaya	*Andrographis paniculata, Boerhavia diffusa, Sida cordifolia*	Warm water	Neem powder	Morning & evening	40 ml
16	Bahuvalli Arista	*Tinospora crispa, Clitoria ternatea*	Fermented decoction	Jaggery, dry grapes	After food	20 ml
17	Nishkumbhadi Vati	*Justicia adhatoda, Costus speciosus*	Compressed tablet	Talcum base, starch	Before sleep	1 tablet
18	Patoladi Churna	*Pongamia pinnata, Calotropis gigantea*	Dry powder	Black salt	Before lunch	1-2 gm with water
19	Jirakadya Mantha	*Cymbopogon citratus, Zingiber officinale, Murraya koenigii*	Cold infusion	Cumin seed extract	Early morning	50 ml
20	Bhringapatri Leha	*Lawsonia inermis, Ocimum gratissimum*	Herbal paste	Honey, sesame oil	Nighttime	1 tsp
21	Tripratyayadi Vati	*Desmodium gangeticum, Bacopa monnieri, Achyranthes aspera*	Tablet	Cow milk binder	After food	2 tablets
22	Tiktakarista	*Cassia auriculata, Terminalia chebula, Vitex negundo*	Fermented decoction	*Cinnamon* bark	Evening	20 ml
23	Raktashodhini Ras	*Stephania japonica, Lygodium flexuosum*	Decoction	Dried amla, turmeric	Early evening	30 ml
24	Nayabindu Taila	*Didymocarpus pedicellata, Aloe vera*	Medicated oil	Castor oil, Camphor	External use (abdomen)	5 ml massage
25	Jambupatra Kashaya	*Syzygium cumini, Mangifera indica, Terminalia bellirica*	Water decoction	Cumin, coriander	Before breakfast	40 ml

26	Srotoshodhaka Arista	*Holarrhena pubescens, Swertia chirata*	Fermented decoction	Fennel, jaggery	After lunch	15-20 ml

Table 5. Community Consensus, Use Pattern, and Perceived Effectiveness of Traditional Antidiabetic Polyherbal Combinations

S.No	Main Plant Ingredients	IP	IR	UR	RFC	CI	Source of Knowledge	Perceived Effectiveness
1	*Momordica charantia, Syzygium cumini*	89	87	102	0.85	0.97	Inherited	Highly effective
2	*Andrographis paniculata, Aegle marmelos, Ficus racemosa*	90	88	102	0.86	0.97	Learned from healer	Moderately effective
3	*Syzygium cumini, Phyllanthus emblica*	102	99	96	0.97	0.91	Inherited	Highly effective
4	*Terminalia chebula, T. bellirica, P. emblica*	95	91	99	0.90	0.94	Community shared	Moderately effective
5	*Didymocarpus pedicellata, Terminalia pallida*	104	103	110	0.99	1.05	Learned from healer	Highly effective
6	*Momordica charantia, Zingiber officinale*	96	95	94	0.91	0.90	Self-experimented	Highly effective
7	*Gymnema sylvestre, Ocimum gratissimum, Cassia auriculata*	98	96	95	0.93	0.90	Inherited	Moderately effective
8	*Boerhavia diffusa, Tinospora cordifolia*	100	98	96	0.95	0.91	Community shared	Highly effective
9	*Mangifera indica, Cajanus scarabaeoides, Swertia chirata*	98	95	100	0.93	0.95	Inherited	Ineffective
10	*Bauhinia variegata, Lawsonia inermis*	85	83	80	0.81	0.76	Learned from healer	Moderately effective
11	*Gymnema sylvestre, Abroma augusta*	99	96	94	0.94	0.90	Inherited	Highly effective
12	*Cassia occidentalis, Azadirachta indica, Vitex negundo*	101	99	98	0.96	0.93	Community shared	Moderately effective
13	*Terminalia arjuna, Helicteres isora*	98	96	97	0.93	0.92	Learned from healer	Highly effective
14	*Averrhoa carambola, Murraya koenigii*	96	94	91	0.91	0.87	Inherited	Moderately effective
15	*Andrographis paniculata, Boerhavia diffusa, Sida cordifolia*	92	90	97	0.88	0.92	Learned from healer	Highly effective
16	*Tinospora crispa, Clitoria ternatea*	89	88	92	0.85	0.88	Self-experimented	Moderately effective
17	*Justicia adhatoda, Costus speciosus*	103	100	101	0.98	0.96	Community shared	Moderately effective
18	*Pongamia pinnata, Calotropis gigantea*	96	94	99	0.91	0.94	Inherited	Moderately effective
19	*Cymbopogon citratus, Zingiber officinale, Murraya koenigii*	98	95	99	0.93	0.94	Community shared	Highly effective
20	*Lawsonia inermis, Ocimum gratissimum*	100	98	102	0.95	0.97	Self-experimented	Moderately effective
21	*Desmodium gangeticum, Bacopa monnieri, Achyranthes aspera*	99	98	100	0.94	0.95	Learned from healer	Highly effective
22	*Cassia auriculata, Terminalia chebula, Vitex negundo*	90	88	102	0.86	0.97	Community shared	Highly effective
23	*Stephania japonica, Lygodium flexuosum*	101	99	101	0.96	0.96	Inherited	Moderately effective
24	*Didymocarpus pedicellata, Aloe vera*	98	97	102	0.93	0.97	Learned from a healer	Highly effective
25	*Syzygium cumini, Mangifera indica, Terminalia bellirica*	96	95	96	0.91	0.91	Inherited	Highly effective
26	*Holarrhena pubescens, Swertia chirata*	90	87	98	0.86	0.93	Learned from healer	Moderately effective

Commonly Used Polyherbal Combinations

Several prominent polyherbal combinations were identified. The pairing of *Didymocarpus pedicellata* and *Terminalia pallida* ranked highest in both RFC and CI, showing strong healer-based trust. The classic blend of *Momordica charantia* and *Syzygium cumini* was another widely cited remedy for blood sugar control.

Combinations such as *Syzygium cumini* with *Phyllanthus emblica* supported glucose and liver regulation, while *Boerhavia diffusa* with *Tinospora cordifolia* was valued for immune and hepatic protection. Other notable pairs included *Gymnema sylvestre* with *Abroma augusta* (insulin sensitivity), and *Cassia occidentalis*, *Azadirachta indica*, and *Vitex negundo* (detox and skin health).

Healer-taught formulations like *Desmodium gangeticum* with *Bacopa monnieri* and *Achyranthes aspera* were used for cognitive and systemic health. The classical *Triphala* combination remained central for digestion and detoxification. Table 5 summarizes these combinations along with IP, IR, UR, RFC, CI, and perceived effectiveness.

Transmission and Perceived Effectiveness of Traditional Knowledge

Knowledge of antidiabetic plants was transmitted mainly through inheritance (34.6%) and healer instruction (30.8%). Community sharing accounted for 23.1%, while self-experimentation contributed 11.5%, reflecting both traditional continuity and personal innovation.

The *Didymocarpus pedicellata* + *Terminalia pallida* achieved the highest RFC (0.99), reflecting its healer-taught origin and high perceived effectiveness. Other top-ranked combinations, such as *Syzygium cumini* + *Phyllanthus emblica* and *Boerhavia diffusa* + *Tinospora cordifolia,* were mainly inherited or community-shared and rated highly effective.

Some formulations, like *Justicia adhatoda* + *Costus speciosus* and *Lawsonia inermis* + *Ocimum gratissimum*, though frequently cited, had moderate effectiveness ratings—indicating popularity based on availability rather than efficacy. An exception was *Mangifera indica* + *Cajanus scarabaeoides* + *Swertia chirata*, which ranked high in RFC but was considered ineffective.

Overall, inherited and healer-derived knowledge forms the backbone of ethnomedicinal practice. High RFC values correspond with perceived efficacy, validating community trust. However, discrepancies between citation frequency and actual effectiveness point to areas requiring scientific re-evaluation and standardisation.

Discussion

Ethnobotanical Significance and Consensus Use

The present ethnobotanical study conducted in the coastal districts of Odisha provides valuable insights into the enduring relevance and pharmacological potential of traditional polyherbal formulations for diabetes management. Among the 26 identified plant combinations, a few emerged as culturally significant and pharmacologically promising based on metrics like Relative Frequency of Citation (RFC), Use Report per Participant (UR/N), and Cultural Importance Index (CI). Most notably, the pairing of *Didymocarpus pedicellata* and *Terminalia pallida* stood out with the highest consensus values, reflecting widespread community use, healer-transmitted knowledge, and perceived efficacy in glycemic control. These findings highlight the sophisticated empirical framework through which these combinations have evolved over generations.

Phytochemical Profile and Pharmacological Potential

Didymocarpus pedicellata, commonly known as Shilapushpa, is well-documented in Ayurvedic medicine for its antiurolithiatic and nephroprotective properties. Its bioactive compounds-flavonoids, chalcones, triterpenes, and steroids such as didymocarpene and pedicellin (Nanjala *et al*., 2022)-exhibit antioxidant, anti-inflammatory, and hypoglycemic activity. Pharmacokinetic studies in streptozotocin-induced diabetic rats show that co-administration with gliclazide enhances hypoglycemic effects, though repeated dosing may alter drug metabolism (Singh *et al*., 2025). Its nephroprotective role is linked to reducing urinary oxalate levels and oxidative stress.

Similarly, *Terminalia pallida* fruits and leaves contain hydrolyzable tannins, gallic acid, and ellagic acid, which contribute to antioxidant and lipid-lowering properties. Experimental models have shown reductions in serum cholesterol, triglycerides, and LDL, alongside increases in HDL (Saleem *et al*., 2024). Cardioprotective effects observed in myocardial infarction models further validate its traditional use in managing diabetes with cardiovascular complications (Harrasi *et al*., 2022).

Synergistic Polyherbal Formulations

Several other plant combinations documented in the study demonstrated significant ethnomedicinal value. For instance, *Syzygium cumini* with *Phyllanthus emblica* is rich in jamboline and ellagic acid, modulating insulin sensitivity and suppressing sugar absorption (Sharma *et al*., 2019). *Boerhavia diffusa* with *Tinospora cordifolia* combines hepatoprotective and insulinotropic effects (Ghosh *et al*., 2024A), while *Momordica charantia* with *Zingiber officinale* enhances glucose uptake via charantin and polypeptide-p (Ghosh *et al*., 2024B; Hafeez *et al*., 2023). Formulations with *Gymnema sylvestre*, *Ocimum gratissimum*, or *Abroma augusta* target glucose absorption, beta-cell regeneration, and antioxidant defenses (Ditchou *et al*., 2024).

Other notable species include *Andrographis paniculata*, *Aegle marmelos*, *Ficus racemosa*, and *Terminalia chebula*, contributing systemic cleansing, antidiabetic, and antioxidant benefits (Suemanotham *et al*., 2023; Kaur *et al*., 2024). Less frequently cited but pharmacologically promising plants—*Desmodium gangeticum*, *Costus speciosus*, *Justicia adhatoda*, *Lawsonia inermis*, and *Calotropis gigantea*—were also integrated into effective combinations, supporting multi-organ modulation in diabetes (Khattak *et al*., 2024; Musfiroh *et al*., 2024).

Molecular Mechanisms and Multi-Targeted Effects

Many of the studied plants influence complex signalling networks regulating glucose homeostasis and metabolic function. Phytochemicals such as gymnemic acids, charantin, berberine, and flavonoids modulate alpha-amylase and alpha-glucosidase activity, AMP-activated protein kinase (AMPK), insulin receptor substrate (IRS), and PI3K/Akt pathways (Borozdina *et al*., 2024; Hassan *et al*., 2023). These mechanisms enhance GLUT4-mediated glucose uptake, improve insulin sensitivity via PPAR-γ/α, downregulate PTP1B, and regulate antioxidant pathways including Nrf2 and NF-κB, addressing oxidative stress and chronic inflammation associated with type 2 diabetes (Parveen *et al*., 2021; Zhang *et al*., 2021).

Synergistic effects in polyherbal formulations further enhance efficacy, bioavailability, and receptor sensitivity across multiple organs. For example, *Tinospora cordifolia* with *Boerhavia diffusa* improves hepatic glucose regulation, while *Syzygium cumini* with *Phyllanthus emblica* enhances mitochondrial function and reduces lipid peroxidation in pancreatic tissues (Pande *et al*., 2021; Sridevi & Thirumal, 2025). Network pharmacology and transcriptomic analyses reveal upregulation of insulin-responsive genes and downregulation of gluconeogenic enzymes (PEPCK, G6Pase), with some metabolites acting as epigenetic modulators through HDAC inhibition or SIRT1 activation (Alhamhoom *et al*., 2024). A list of plants with their phytochemical composition, pharmacological actions, and molecular mechanisms of antidiabetic medicinal species obtained from the survey has been mentioned in Table 6.

Sustainability and Traditional Preparation Practices

Most highly cited plants are either cultivated or harvested non-destructively from wild or semi-wild habitats. *Terminalia pallida* fruits are collected without harming the tree, while *Didymocarpus pedicellata* regenerates seasonally from rocky slopes (Zahoor *et al*., 2024). Such practices demonstrate an ecological ethic intrinsic to traditional medicine, valuing long-term sustainability. Preparation methods-decoctions, powders, pastes, and infusions—ensure accessibility, simplicity, and independence from industrial processes (Ali *et al*., 2024). Less effective historical combinations, such as *Mangifera indica* with *Swertia chirata* and *Cajanus scarabaeoides*, highlight the need for ongoing community evaluation and scientific validation (Bhattacharya *et al*., 2024).

Future Scope

Future research can build upon this ethnobotanical survey by conducting detailed phytochemical and pharmacological investigations of polyherbal formulations documented in Odisha's coastal communities. Studies focusing on the isolation of bioactive compounds, identification of synergistic interactions, and the standardization of extracts will provide a scientific foundation for developing multi-target antidiabetic therapies. Researchers can explore mechanistic studies using in vitro and in vivo models to understand how these formulations influence key metabolic pathways, insulin signalling, oxidative stress, and inflammation. There is also scope for clinical translation, where well-designed trials can evaluate efficacy, safety, and potential herb-drug interactions of selected polyherbal formulations. Systems biology and network pharmacology approaches could help predict multi-component interactions and guide the design of combination therapies. Sustainability and conservation research is another important avenue. Investigations into cultivation practices, propagation methods, and community-based conservation strategies can ensure long-term availability of medicinal plants while preserving traditional knowledge. Future researchers can also explore the digitization of ethnobotanical knowledge, the creation of databases, and integration with modern informatics tools for wider accessibility and cross-cultural validation. Additionally, the unique cultural context of Odisha's coastal communities provides opportunities to study region-specific formulations and their relevance in managing metabolic disorders, paving the way for locally tailored, culturally acceptable, and integrative healthcare solutions.

Table 6. Phytochemical Composition, Pharmacological Actions, and Molecular Mechanisms of Antidiabetic Medicinal Plant Species obtained from the survey.

Species Name	Major Chemical Constituents	Pharmacological Action	Molecular Mechanism in Diabetes	References
Gymnema sylvestre	Gymnemic acids, gurmarin, flavonoids	Hypoglycemic, β-cell regeneration	Inhibits glucose absorption, stimulates insulin, β-cell protection	Acharya *et al*., 2024
Momordica charantia	Charantin, polypeptide-p, triterpenoids, flavonoids	Hypoglycemic, insulin-mimetic	Enhances insulin, inhibits carb enzymes, improves glucose uptake	Agrawal & Kulkarni, 2023
Coccinia grandis	Quercetin, flavonoids, alkaloids	Hypoglycemic, antioxidant	Inhibits α-amylase/glucosidase, enhances insulin	Akter *et al*., 2024
Syzygium cumini	Jamboline, ellagic acid, quercetin	Hypoglycemic, antioxidant	Enhances insulin, modulates PPARγ, β-cell protection	Bhatt & Sharma, 2025
Trigonella foenum-graecum	Diosgenin, trigonelline, galactomannan, saponins	Hypoglycemic, insulin secretagogue	Stimulates insulin, inhibits carb digestion	Chintanippula & Chowdhury, 2024
Tinospora cordifolia	Tinosporaside, alkaloids, diterpenes	Hypoglycemic, antioxidative	Activates PI3K/AMPK, DPP-4 inhibition, β-cell regeneration	Chi *et al*., 2016
Terminalia chebula	Chebulic acid, gallic acid, tannins	Hypoglycemic, lipid lowering	Reduces glycation, β-cell support, antioxidant	Cordiano *et al*., 2025
Andrographis paniculata	Andrographolide, flavonoids	Hypoglycemic, anti-inflammatory	Upregulates GLUT4, suppresses NF-κB, ↑ insulin sensitivity	Dhara *et al*., 2024
Aegle marmelos	Marmelosin, aegeline, coumarins	Hypoglycemic, antioxidant	Enhances glucose uptake, β-cell protection	Gandhi *et al*., 2012
Cassia auriculata	Flavonoids, anthraquinones, tannins	Hypoglycemic, antioxidant	Inhibits carb enzymes, improves insulin response	Gwata *et al*., 2025
Didymocarpus pedicellata	Flavonoids, saponins	Antioxidant, antihyperglycemic	Protects β-cells, reduces oxidative stress	Harini *et al*., 2025
Terminalia pallida	Tannins, flavonoids, triterpenoids	Hypoglycemic, antioxidant	Increases insulin, inhibits carb enzymes	Ismail *et al*., 2024
Desmodium gangeticum	Alkaloids, flavonoids, saponins	Antioxidant, antidiabetic	Stimulates insulin, blocks carb-digesting enzymes	Jachak *et al*., 2024
Clerodendrum indicum	Flavonoids, clerodin, saponins	Hypoglycemic, antioxidant	Stimulates insulin, inhibits carb digestion	Jayaweera *et al*., 2024
Holarrhena pubescens	Conessine, alkaloids, flavonoids	Hypoglycemic, anti-inflammatory	Inhibits carb enzymes, improves insulin secretion	Karpe *et al*., 2025
Dillenia indica	Betulinic acid, flavonoids, phenolic acids	Hypoglycemic, antioxidant	Protects β-cells, reduces oxidative stress	Kadyan *et al*., 2025
Justicia adhatoda	Vasicine, flavonoids, alkaloids	Hypoglycemic, anti-inflammatory	Enhances insulin, protects β-cells	Khan & Kibria, 2024
Eugenia heyneana	Flavonoids, essential oils	Antioxidant, hypoglycemic	Improves insulin function, antioxidant enzyme modulation	Khan *et al*., 2024
Murraya koenigii	Mahanimbine, carbazole alkaloids, flavonoids	Hypoglycemic, insulin secretagogue	Stimulates insulin, delays carb absorption	Kumar *et al*., 2025
Tinospora crispa	Tinosporaside, diterpenoids	Hypoglycemic, antioxidant	Increases insulin, reduces glucose absorption	Kumar *et al*., 2024a (Sida cordifolia)
Cajanus scarabaeoides	Isoflavonoids, flavonoids, phenolics	Hypoglycemic, antioxidant	Enhances insulin, inhibits digestive enzymes	Kumaravelu *et al*., 2025
Pterocarpus marsupium	Pterostilbene, marsupsin, tannins	Regenerates β-cells, hypoglycemic	Stimulates β-cell regrowth, inhibits glucose absorption	Kumari *et al*., 2024
Ocimum gratissimum	Eugenol, flavonoids, terpenes	Hypoglycemic, antioxidant	Enhances insulin, reduces oxidative stress	Lestari *et al*., 2023

Ficus racemosa	Leucocyanidin, β-sitosterol, tannins	Hypoglycemic, antioxidant	Improves insulin activity, inhibits carb enzymes	Mahomoodally *et al*., 2012
Swertia chirata	Swertiamarin, amarogentin, xanthones	Hypoglycemic, antioxidant	Stimulates insulin, reduces oxidative stress	Malik *et al*., 2025
Bauhinia variegata	Flavonoids, saponins, alkaloids	Hypoglycemic, antioxidative	Enhances insulin, reduces glucose absorption	Mohan *et al*., 2020
Mangifera indica	Mangiferin, polyphenols, triterpenoids	Hypoglycemic, antioxidant	Inhibits carb enzymes, enhances glucose uptake	Moreno-Vargas *et al*., 2024
Zingiber officinale	Gingerols, shogaols, paradols	Hypoglycemic, anti-inflammatory	Enhances insulin sensitivity, reduces oxidative stress	Nille *et al*., 2021
Abroma augusta	Flavonoids, alkaloids, saponins	Hypoglycemic, antioxidant	Stimulates insulin, reduces glucose absorption	Nenni & Karahuseyin, 2024
Averrhoa carambola	Flavonoids, oxalate, saponins	Hypoglycemic, antioxidant	Enhances insulin, antioxidant enzyme modulation	Neto *et al*., 2024
Aloe vera	Aloin, aloe-emodin, polysaccharides	Hypoglycemic, antioxidant	Increases insulin secretion, improves glucose metabolism	Pangavhane & Pache, 2025
Lawsonia inermis	Lawsone, flavonoids, tannins	Antioxidant, hypoglycemic	Improves β-cell function, reduces oxidative stress	Pathak *et al*., 2024
Phyllanthus emblica	Emblicanin, gallic acid, ellagic acid	Hypoglycemic, potent antioxidant	Enhances insulin, blocks α-glucosidase	Pradhan *et al*., 2025
Boerhavia diffusa	Punarnavine, flavonoids, alkaloids	Antioxidant, hypoglycemic	Stimulates insulin, inhibits carb-digesting enzymes	Ramjan *et al*., 2025
Sida cordifolia	Ephedrine, flavonoids, alkaloids	Hypoglycemic, antioxidant	Enhances insulin activity, reduces oxidative load	Rani *et al*., 2024
Cymbopogon citratus	Citral, flavonoids, essential oils	Hypoglycemic, antioxidant	Inhibits carb enzymes, improves glucose tolerance	Saka *et al*., 2024
Stephania japonica	Alkaloids (stepharanine), flavonoids	Hypoglycemic, antioxidant	Improves insulin activity, reduces oxidative damage	Saqulain *et al*., 2025
Lygodium flexuosum	Flavonoids, phenolic acids	Hypoglycemic, antioxidant	Enhances insulin secretion, antioxidant support	Sharma *et al*., 2024
Terminalia bellirica	Gallic acid, ellagic acid, chebulagic acid	Hypoglycemic, lipid lowering	Reduces oxidative stress, stimulates insulin	Sheethal *et al*., 2025
Costus speciosus	Diosgenin, saponins, alkaloids	Hypoglycemic, antioxidant	Upregulates insulin, inhibits glucose absorption	Shukla *et al*., 2025
Azadirachta indica	Azadirachtin, nimbolide, flavonoids	Hypoglycemic, anti-inflammatory	Stimulates insulin, inhibits digestive enzymes	Singh & Bharadvaja, 2025
Cassia occidentalis	Anthraquinones, flavonoids, alkaloids	Antioxidant, hypoglycemic	Blocks carb-digesting enzymes, enhances insulin	Song *et al*., 2022
Pongamia pinnata	Pongamol, flavonoids, karanjin	Hypoglycemic, antioxidant	Improves insulin secretion, antioxidant activity	Tabassum & Ahmad, 2021
Terminalia arjuna	Tannins, arjunic acid, flavonoids	Hypoglycemic, cardioprotective	Enhances insulin, reduces oxidative damage	Tahir *et al*., 2025
Vitex negundo	Flavonoids, casticin, alkaloids	Hypoglycemic, antioxidant	Upregulates insulin, reduces glucose absorption	Tiwari *et al*., 2024
Calotropis gigantea	Calotropin, flavonoids, cardiac glycosides	Antioxidant, hypoglycemic	Enhances insulin, potentiates β-cell function	Van *et al*., 2024
Helicteres isora	Flavonoids, sterols, saponins	Hypoglycemic, antioxidant	Improves glucose uptake, stimulates insulin	Valsa *et al*., 2021
Bacopa monnieri	Bacoside A/B, flavonoids, saponins	Hypoglycemic, neuroprotective	Enhances insulin, reduces oxidative stress	Widowati *et al*., 2024
Achyranthes aspera	Ecdysterone, alkaloids, saponins	Antidiabetic, antioxidant	Increases insulin, inhibits carb-digesting enzymes	Yadav *et al*., 2024
Clitoria ternatea	Ternatins, anthocyanins, flavonoids	Hypoglycemic, antioxidant	Enhances insulin secretion, modulates carb enzymes	Yadav *et al*., 2025

Conclusion

The ethnobotanical exploration of antidiabetic plant use in Odisha's coastal communities confirms a deeply rooted and culturally sustained herbal knowledge system. A total of fifty plant species and twenty-six polyherbal formulations were documented, reflecting not only the rich botanical diversity but also the community's reliance on synergistic interactions among multiple plants. Among these, Terminalia pallida and Didymocarpus pedicellata emerged as particularly significant due to their consistent use and high cultural importance, validated by quantitative ethnobotanical indices. Unlike many previous studies that focus on single plants or inland regions, this research uniquely highlights polyherbal formulations in the coastal belt of Odisha, a region characterised by ecological and cultural heterogeneity, where diverse tribal and non-tribal communities maintain a living tradition of herbal medicine. Many of the documented formulations are known to influence key metabolic regulators, including AMPK, PTP1B, and insulin signalling pathways, and frequently integrate antioxidant, hepatoprotective, and nephroprotective herbs, demonstrating a sophisticated community-level understanding of diabetes as a systemic disorder. Sustainable harvesting practices and simple preparation methods further ensure replicability and ecological stewardship, enhancing the relevance of these remedies in modern contexts. While some widely used combinations were found to be less effective, the study underscores the importance of ongoing scientific validation to optimise formulation efficacy. The novelty of this study lies in its focus on traditional polyherbal combinations within a specific coastal context, capturing region-specific knowledge that has been largely underexplored. These findings offer a valuable foundation for future pharmacological research, including in vitro and in vivo testing of multi-plant extracts, as well as clinical investigations to assess safety, efficacy, and potential synergistic effects. By bridging traditional wisdom with modern biomedical research, this work provides a roadmap for developing culturally acceptable, affordable, and effective antidiabetic interventions, while preserving invaluable ethnobotanical knowledge for future generations.

Declaration

List of Abbreviations: RFC: Relative Frequency of Citation; **CI**: Cultural Importance Index; **UR**: Use Report; **IP**: Informant Participant; **IR**: Informant Response; **AMPK**: AMP-activated Protein Kinase; **PTP1B**: Protein Tyrosine Phosphatase 1B; **SHG**: Self-Help Group

Ethics approval and consent to participate: Verbal prior informal information consent was obtained before the survey

Consent for publication: People who participated in this study gave their prior informed consent for the publication of the article and their images.

Availability of data and material: All the supporting data available in the article

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