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Traditional antidiabetic medicinal plants of Himachal Pradesh: ethnomedicinal evidence and drug-discovery potential

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Diabetes mellitus is a rapidly increasing lifestyle disorder posing a serious global health threat. This review specifically focuses on indigenous medicinal plants of Himachal Pradesh, India, a region rich in ethnomedicinal diversity. The primary objective of this review is to systematically compile and analyze the ethnomedicinal, phytochemical, and pharmacological evidence of antidiabetic plants used in this region. Data were collected from various scientific sources including Scopus, PubMed, ScienceDirect, Google Scholar, ResearchGate, books, and other relevant literature from published studies spanning the period from 1995 to 2025. According to literature, 80 ethnomedicinal herbs are believed to be effective in treating diabetes. For the preparation of natural remedies, different plant parts were often used such as roots (17%), leaves (24%), fruits (15%), bark (13%), whole plants (3%), and flowers (3%). These plants are widely used in the traditional healthcare practices of Himachal Pradesh. Furthermore, the review highlights traditionally used medicinal plants for diabetes management, along with the reported phytochemicals responsible for their antidiabetic activity. Moreover, available preclinical *in-vivo* studies on selected plants have been included to support their therapeutic potential. Furthermore, we suggest that future studies should include molecular docking analysis of the reported antidiabetic phytochemicals to better understand their mechanism of action at the molecular level. Additionally, conservation and sustainable utilization of these indigenous plant resources are crucial for future therapeutic applications.

KEYWORDS

diabetes, ethnobotany, ethnopharmacology, medicinal plants, phytoconstituent

1 Introduction

Nearly 80% of the population is projected to rely on plant-based remedies to treat various disorders as they are safe, cost-efficient, easily accessible, and extremely effective (1). India is also known as the “botanical garden of the world” due to its tremendous diversity, and much more than 70% of its rural areas rely on traditional plant medicines (2). Himachal Pradesh (HP) is a hilly state, with latitudes ranging from 30°22′44″ N to 33°12′44″N and longitudes ranging from 75°45′44″E to 79°04′20″E (3). HP is endowed with an abundance of plant diversity, as well as medicinal properties and other valuable species (4).

The medicinal flora has developed an extensive variety of therapies, including diabetes mellitus (DM), a disease whose “killer” nature and epidemic severity pose a challenge to humanity (5). The disease rate is expected to reach 366 million by 2030, primarily in China and India. Among diabetics, there are three types: type 1 diabetes (T1DM), type 2 diabetes (T2DM), and gestational diabetes (GDM) (6). Diabetic complications are most prevalent among people with type 2 diabetes, which is characterized by hyperglycemia oxidative stress, and hyperlipidemia, which can cause chronic problems with the nerves, eyes, blood vessels, and kidneys (7).

Several traditional medicines and plants are well-known for delaying and preventing the development of diabetes-related problems and changing metabolic imbalances (8). Furthermore, the existence of phytoconstituents, plants have a larger potential than manufactured medications (9). One of the primary benefits of using plants is that they do not have negative side effects that are frequently associated with other medications (1). All the drugs have a significant mechanism, limited efficacy, and tolerability (10). Over the last decades, there has been an immense interest in discovering the secrets of natural treatments due to biological screening, isolation, and clinical trials of plants that have been developed for this purpose (11). Around 1,200 herbal treatments for diabetes have been reported; 343 species were studied for their capability to lower sugar level, and 656 species of flowering plants are usually used for the treatment of diabetes in Asian cultures (8).

The Ayurvedic Pharmacopeia Committee includes 350 plant species (Government of India), of which 225 species are found in Himachal Pradesh and are commercially available (12). Various medicinal plants are extensively described in the Rigveda (2500–1800 BC), Charaka Samhita, and Sushruta (13, 14). Potential phytochemicals that possess drug-like and pharmacophore properties could provide a novel scaffold for combinatorial preparations (15). As there are certainly available medications, diabetes patients still struggle to maintain adequate hyperglycemia control due to continuing declines in β -cell function (16).

Nowadays ethnomedicinal information that is orally passed down through generations is at risk so it can be forgotten or lost forever (17). However, this information can be retained, preserved, and sustainably applied for diagnosing and inhibiting diabetes in humans in the long run as mentioned in Table 1. New drugs or medicines can be created using this knowledge of medicinal plants. This review article aims to focus on the mechanisms of phytochemicals used as prototypes for synthesizing new molecules to lower glucose level and enhance insulin secretion. In contrast to a simple review article, this work delves into mechanisms that could provide an insight into how medicinal plants could be used for the treatment of diabetes based on scientific literature. It is known that

natural products derived from medicinal plants like flavonoids, alkaloids, and terpenoids act in an antidiabetic manner by increasing insulin secretion, increasing insulin sensitivity, and reducing glucose uptake in the intestines. Moreover, medicinal plant-derived phytochemicals possess antidiabetic potential through multi-target mechanisms and can be further validated using molecular docking to understand their interaction with key proteins. This review incorporates ethno-medicinal information, phytochemistry, and *in-vivo* studies of medicinal plants from Himachal Pradesh for antidiabetic therapy, providing valuable scientific insight.

2 Materials and methods

An extensive compilation of information on the use of ethno-medicinal plants in the treatment of diabetes disorder was compiled from a variety of sources, including literature, books, and relevant publications on Google Scholar, Research Gate, Science Direct, Scopus, and PubMed, etc. Detailed information on the collected plants is given in tabular form, including their botanical name. In this review, data were systematically collected from published studies spanning the period from 1995 to 2025. The plant species was identified and its nomenclature verified using the database available at <https://www.plantlist.com/>.

3 The current state and treatment of diabetes

Diabetes is characterized by hyperglycemia (high blood sugar) because of an inability to produce insulin. The inability of cells to produce insulin is known as insulin resistance (IR) (18). In addition to diabetes, IR has been linked to the development of metabolic syndrome and cardiovascular disease (19). T1DM is caused by the death of cells, resulting in a deficiency of insulin synthesis (20). T2DM is caused by insulin resistance and an inability to respond appropriately to hyperglycemia, and it affects most diabetics (90–95%) gestational diabetes is due to high level of sugar in the blood during pregnancy as described in Figure 1.

According to an epidemiological study, DM is preceded by endocrine diseases (21). It is expected that diabetes will be one of the leading causes of death in the 21st century (22). Herbal components are the most prolific source of novel pharmacological entities, with diverse medicinal indications and chemical structures (23). Several diabetes treatments with disease-causing actions have already been identified (24). An example is treatment with anakinra that blocks the effects of interleukin-1 α and β cells (25). Both forms of interleukin-1 are produced by many cells (e.g., beta cells), play positive roles in host defense, and induce β -cell apoptosis (26). Treatment with an interleukin-1 receptor antagonist is shown in Figure 2 and was permitted by the Food and Drug Administration in 2001 (27, 28).

The vast pervasiveness, progressive nature, variable pathogenesis, and repercussions of diabetes highlight the urgent requirement for effective therapies (29). Despite considerable advances in diabetes therapy, patient health outcomes are still far from satisfactory (30). Many approaches are recommended now as plants contain

TABLE 1 A list of most common medicinal herbs used for the management of diabetes.

Botanical name	Common name	Plant part used	Mode of application	Place	References
<i>Acacia arabica</i> (Lam.) Willd.	Kikar, Babul	Gum	As a decoction	Hamirpur	(48)
<i>Acacia nilotica</i> (L.) Delile	Kikar	Flower, leaves and seeds	Used decoction, powder, orally and Juice forms	Mandi, Sirmaur, Solan and Una	(9)
<i>Aconitum heterophyllum</i> Wall. ex Royleall. ex-Royle	Atish, Patish	Roots	Aa a decoction	Shimla	(49)
	Atish and Patish	Whole plant	Root extract is taken orally three times in each day	Lahaul and Spiti	(50)
<i>Acacia nilotica</i> (L.) Delile	Bil and Blpatri	Leaves	Juice, decoction, and powder	Hamirpur	(48)
<i>Aegle marmelos</i> (L.) Corrêa	Dhardu	Fruit and leaves	Decoction and as a juice	Hamirpur	(51)
<i>Ajuga bracteosa</i> Wall. ex Benth	Neelkanthi/Jwara	Leaves	About 5–10 leaves are taken	Chamba	(52)
<i>Bulga parviflora</i> (Benth.) Kuntze	Neelkanthi	Leaves	Juice	Una	(53)
	Neelkanthi	Leaves	Fresh leaves are chewed	Shimla	(54)
<i>Aconitum heterophyllum</i> Wall. ex-Royle	Kalasiri	Bark, flowers, and roots	Decoction	Bilaspur, Chamb, Hamirpur, Sirmaur, Solan and Una	(9)
<i>Allium sativum</i> L.	Lahusan	Bulb	Bulb of the garlic is used as diabetes	Hamirpur	(48)
	Lahasun	Bulb	Bulbs were used to treat diabetes	Solan	(50)
<i>Aloe barbadensis</i> Mill.	Kabbarya	Leaves	Juice, decoction, and powder	Hamirpur	(48)
<i>Anogeissus latifolia</i> (Roxb. ex-DC.) Wall. ex Bedd.	Dhawa, Dhaura	Bark, flowers, fruits, roots, and stems	Powder form	Hamirpur, Sirmaur, Solan and Una	(9)
<i>Argemone mexicana</i> L.	Bharbhand	Root	Root powder is used	Hamirpur	(48)
<i>Asparagus adscendens</i> Roxb.	Sanspai	Roots	Decoction and as a juice	Hamirpur	(51)
<i>Asparagus racemosus</i> Will	Sahanspai	Roots	Taken as powder	Una	(5)
	Shatavri	Rhizome and aerial part	Oral	Kangra	(55)
<i>Azadirachta indica</i> A. Juss.	Neem	Leaves	Juice, decoction, and powder	Hamirpur	(48)
<i>Begonia picta</i> Sm	Pethu	Seeds and fruit	Directly eaten	Mandi	(51)
	Pethu	Pulp, seed, and fruits	Decoction and as a juice	Hamirpur	(51)
<i>Berberis asiatica</i> Roxb. ex-DC.	Kashmal	Roots	Decoction	Mandi	(50)
<i>Berberis lycium</i> Royle	Kasmal	Roots	Decoction	Una	(53)
<i>Bidens pilosa</i> L.	Gumber	Leaves	Decoction and powder of leaves is used diabetes	Solan	(56)
<i>Bougainvillea glabra</i> Choisy	Bouganbael	Leaves	Decoction of leaves	Kangra	(55)
<i>Bougainvillea spectabilis</i> Willd.	Booganbel	Whole plant	Directly eaten	Solan	(56)
<i>Calotropis gigantea</i> (L.) Dryand.	Aak	Bark, roots	Powder of bark with hot water	Kangra	(55)
<i>Cassia fistula</i> L.	Karen and Amaltas	Bark	Powder is used	Hamirpur	(48)
<i>Cassia occidentalis</i> L.	Baru, elwan, relu Jamun	Seed	Seed powder and juice	Hamirpur	(48)
	Sadabahar	Roots and leaves	Decoction of roots and leaves	Solan	(56)
<i>Catharanthus roseus</i> (L.) G. Don	Patindu	Leaves	Fresh leaves are chewed	Una	(5)
<i>Cissampelos pareira</i> L.	Tarbuj	Fruits and seeds	Decoction	Kangra, Sirmaur, Solan, and Una	(57)
<i>Citrullus lanatus</i> (Thunb.) Matsum. & Nakai	Kunduri	Flowers, fruits, leaves and roots	Decoction	Una	(58)
<i>Coccinia grandis</i> (L.) Voigt	Jamun		Leaves taken orally	Chamba	(59)
<i>Corylus jacquemontii</i> Decne	Panja	Tubers	Decoction of fresh or dried tubers	Chamba	(60)

(Continued)

TABLE 1 (Continued)

Botanical name	Common name	Plant part used	Mode of application	Place	References
<i>Dactylorhiza hatagirea</i> (D. Don) Soó	Sisham	Leaves	Juice, decoction, and powder	Hamirpur	(48)
<i>Dalbergia abbreviata</i> Craib	Phunta	Leaves	Orally	Solan	(56)
<i>Erigeron annuus</i> (L.) Pers.	Koda	Seeds	As a decoction or powder	Shimla	(61)
<i>Eleusine coracana</i> (L.) Gaertn.	Chem, Macho, Pret, and Yamkand	Leaves	Young shoots are cooked and used as digestive.	Kullu, Sirmaur and Kinnaur	(58)
<i>Henningia himalaica</i> (Baker) A.P. Khokhr.	Ogla	Seeds and leaves	Both are boiled and eaten	Kinnaur, Shimla, Sirmaur, Solan and Una	(62)
<i>Ficus bengalensis</i> L.	Bar, Bargad, and Bor	Fruits, latex and leaves	Juice	Hamirpur, Shimla, Sirmaur, Solan, Una	(58)
	Bargad/Bar/Bat Vriksh	Young buds	Milky juice	Chamba and Hamirpur	(63)
	Bargad	Bark, Roots and leave	As a decoction or powder	Bilaspur	(64)
<i>Ficus glomerata</i> Roxb.	Gular and Umar.	Bark, leaves and latex	Juice	Kangra Sirmaur, Solan, Una	(58)
	Gular	Roots	Powder of dry roots	Chamba and Hamirpur	(63)
<i>Ficus racemosa</i> L.	Tarayamblu	Fruit, roots	Directly eaten	Mandi	(51)
		Fruits, roots, bark, and latex	Decoction and as a juice	Hamirpur	(51)
<i>Ficus religiosa</i> L.	Pipal	Bark, roots	Decoction of the roots and bark	Solan	(56)
<i>Gentiana kurroo</i> Royle	Karvi	Roots	Powder of roots	Shimla	(61)
<i>Gymnema acuminatum</i> Wall	Kadu	Roots	Root powder taken orally	Shimla	(61)
<i>Helicteres isora</i> L.	Gurmar	Roots	Powder of dry roots	Chamba and Hamirpur	(63)
<i>Ficus religiosa</i> L.	Marorphali	Bark	Decoction	Chamba and Hamirpur	(63)
	Marorphali	Bark, fruits, roots, seeds, and leaves	Decoction	Kangra Sirmaur Solan	(58)
<i>Hordeum vulgare</i> L.	Jau	Seed	Directly eaten	Mandi	(51)
		Seeds	Decoction and as a juice	Hamirpur	(51)
<i>Jasminum officinale</i> L.	Chameli	Leaves	Boiled leaves	Hamirpur and Kangra,	(65)
<i>Juglans regia</i> L.	Walnut	Fruit	Directly	Sirmaur	(50)
<i>Juniperus communis</i> L.	Aaraar	Fruit	Directly eaten	Lahaul and Spiti	(66)
<i>Mallotus philippensis</i> (Lam)	Kamala or Kabila	Fruit	Unripe fruits are found to be useful in diabetes	Chamba and Hamirpur	(63)
<i>Malus pumila</i> Mill.	Seb	Leaves	Decoction	Kullu	(56)
<i>Medicago polymorpha</i> L.	Maina	Leaves	Decoction	Kullu	(63)
<i>Momordica charantia</i> L.	Khukhni	Seeds	Sprouts of seeds used in diabetes	Hamirpur	(67)
<i>Momordica charantia</i> L.	Karela	Fruit	Cooked as vegetable	Hamirpur	(48)
	Karela	Fruit and seeds	Taken as vegetable	Hamirpur	(53)
<i>Momordica dioica</i> Roxb. ex Willd	Kakroon	Fruit	Cooked as vegetable	Hamirpur	(48)
<i>Morina alba</i> Hand.-Mazz.	Sainjna	Bark, leaves, roots, and seeds	Decoction	Kangra Sirmaur Solan and Una	(58)
<i>Moringa oleifera</i> Lam	Moringa	Leaves	Decoction	Mandi	(53)

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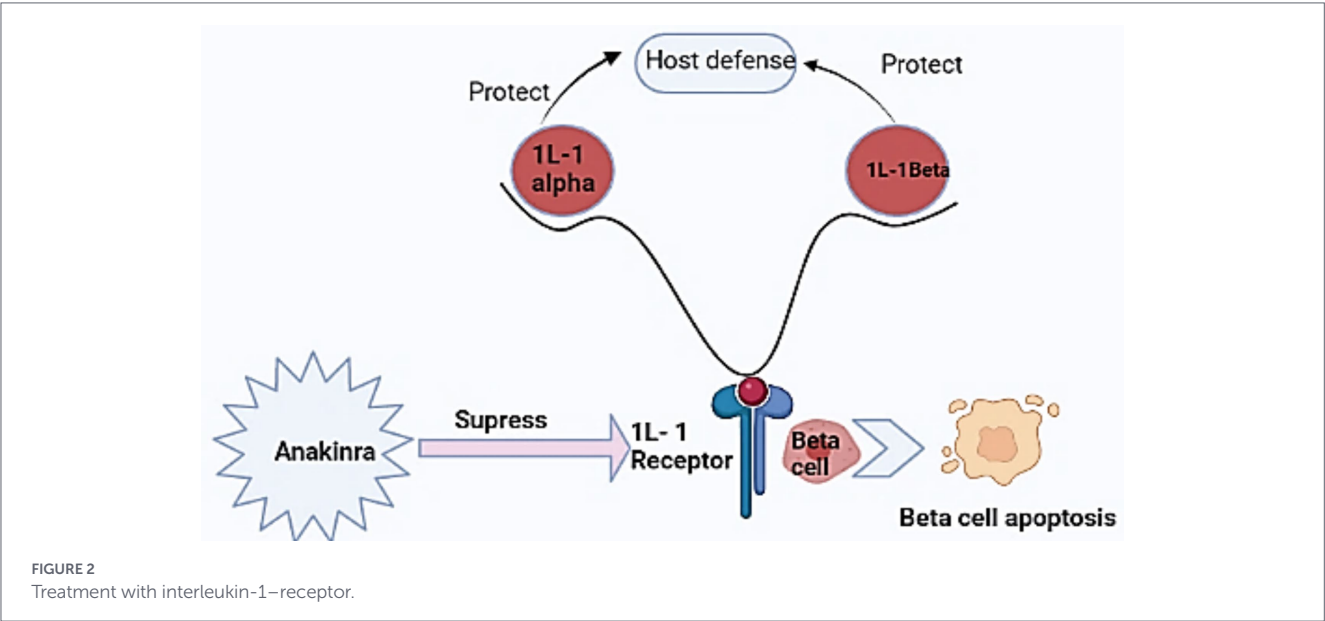
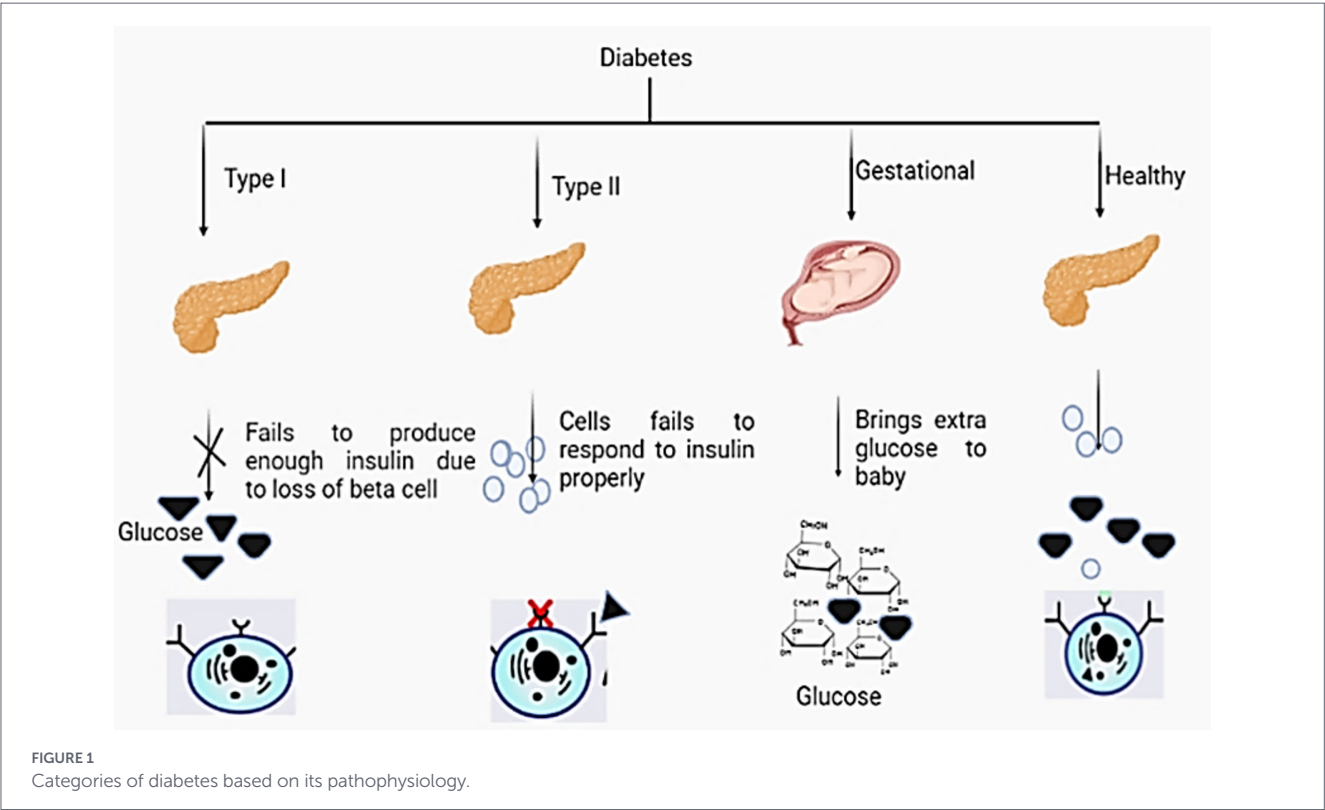
TABLE 1 (Continued)

Botanical name	Common name	Plant part used	Mode of application	Place	References
<i>Morus alba</i> L.	Toot	Fruits	Directly eaten	Solan, Kangra, Chamba and Bilaspur	(68)
<i>Morus nigra</i> L.	Tut	Roots and leaves	Decoction of roots and leaves	Solan	(56)
<i>Murraya koenigii</i> (L.) Spreng	Kari patta	Leaves	Decoction and powder of leaves	Solan	(56)
<i>Musa paradisiaca</i> L.	Kela	Fruit	Unripe fruits are found to be useful in diabetes	Chamba and Hamirpur	(63)
<i>Nerium indicum</i> Mill.	Kaner	Bark, leaves, roots, whole plant	Directly eaten	Bilaspur, Sirmaur Solan and Una	(9)
<i>Opuntia stricta</i> (Haw.) Haw.	Nagphany	Roots	Powder of dry roots	Chamba and Hamirpur	(63)
<i>Paspalum scrobiculatum</i> L.	Kodo and Kodra	Roots, seeds, and stems	Decoction	Hamirpur, Kangra and Una	(9)
<i>Picrorhiza kurooa</i>	Kavi	Roots	Root powder taken orally	Shimla	(69)
<i>Picrorhiza kurroa</i> Royle ex Benth.	Bhekal	Bark	Powdered of bark taken orally twice a day with lukewarm	Chamba	(59)
<i>Prinsepia utilis</i> Royle	Matter	Seeds	Taken as vegetable	Hamirpur	(53)
<i>Pogostemon amaranthoides</i> Benth	Kalibasuti	Leaves	Fresh leaves are chewed	Una	(5)
<i>Pongamia pinnata</i> (L.) Pierre	Karanja	Bark	Powder is used	Hamirpur	(48)
<i>Prunus armeniaca</i> L.	Karanjoatra	Leaves and fruits	As a decoction or powder	Bilaspur	(64)
<i>Punica granatum</i> L.	Anar	Fruit	In the form of powder	Hamirpur	(70)
<i>Rhododendron arboreum</i> Sm.	Burans	Leaves	Taken as powder		(70)
<i>Royalea cinerea</i> (D. Don) Baill.	Karway and Karu	Leaves	Chewing of leaves in the early morning	Mandi, Sirmaur, Shimla, Solan	(71)
<i>Sapindus mukorossi</i> Gaertn.	Ritha	Seeds	Seeds are eaten	Una	(5)
<i>Senegalia tenuifolia</i> (L.) Britton & Rose	Khair	Bark	Infusion of bark with hot water cure diabetes	Kangra	(55)
<i>Swertia chirayita</i> (Roxb.) Buch.-Ham. ex C. B. Clarke	Bhunimba, Chirata and Chirayta	Leaves	Taken as juice	—	(50)
<i>Syzygium cumini</i> (L.)	Jam	Bark, fruits, leaves and seeds	Orally	Chamba, Hamirpur, Mandi, Sirmaur, Una	(9)
	Jamun	Seeds	Seeds powder and juice	Hamirpur	(48)
	Jamun	Leaves	Decoction and powder of leaves is used diabetes	Solan	(56)
	Jamun	Leaves and seeds	Directly eaten	Mandi	(51)
	Jamun	Bark, leaves and seeds	Decoction and as a juice	Hamirpur	(51)
	Jamun	Fruit and leaves	Leaves powder with tea is taken once a day in the morning for a few days	Bilaspur	(64)
	Jamun	Seeds	Decoction of seeds are used	Chamba and Hamirpur	(63)
<i>Terminalia arjuna</i> (Roxb. ex-DC.) Wight & Arn	Arjun	Leaves	Juice, decoction, and powder	Hamirpur	(48)
<i>Tinospora andamaa</i> Diels	Guduchi	Leaves	Decoction	Mandi	(53)
	Giloe, Gulje	Stem	Dried stem pieces are used	Hamirpur	(48)
	Giloe/Gulanj	Stem	Stem of juice is used	Chamba and Hamirpur	(63)
	Giloya	Stem	Decoction of stem	Kangra	(55)
	Giloye	Leaves	Decoction	Kullu	(56)

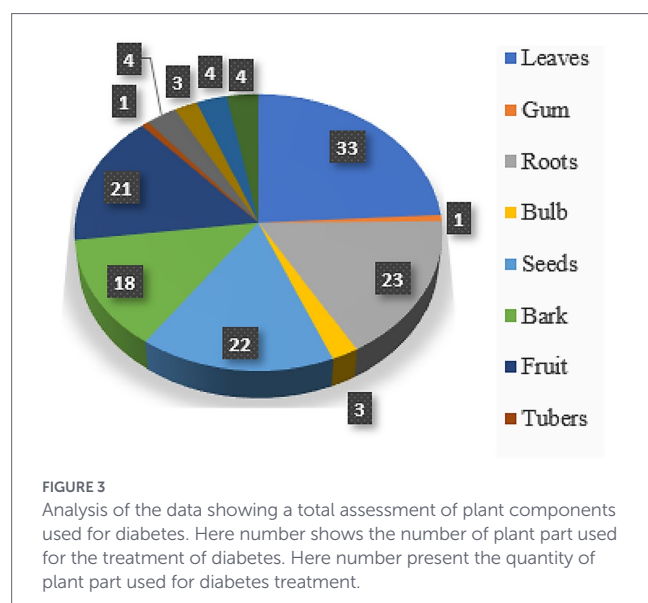
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TABLE 1 (Continued)

Botanical name	Common name	Plant part used	Mode of application	Place	References
<i>Trigonella foenum graecum</i> L.	Methi	Seed	Powdered seed is taken with cold water	Hamirpur	(48)
<i>Vinca rose</i> (L.) G. Don	Sadabahar	Leaves	Juice, decoction, and powder	Hamirpur	(48)
<i>Withania somnifera</i> (L.) Dunal.	Ashvagandha	Roots	Root powder is used	Hamirpur	(48)



chemical compounds with anti-diabetic properties including glycoside, terpenoids, carotenoids, alkaloids, and flavonoids (31). The anti-hyperglycemic effects of plants are often attributed to their ability to restore pancreatic tissue function, achieved by enhancing insulin secretion and reducing glucose absorption in the intestine (32). Several forms of pharmacological investigation on anti-diabetic plants increased the number of individuals who used these natural chemicals to cure their conditions (28). Herbal remedies were used



to treat diabetes before insulin and other blood sugar-lowering agents were discovered (14). A few of the most used plants have been covered in Table 1.

4 Role of plant parts in antidiabetic ethnomedicinal practices

Diabetes has been cured with phytoconstituents present in plant parts like bark, roots, flowers, fruits, leaves, seeds, and sometimes entire plants. This also increases local people's utilization of these plants. All ethnomedicinal plants include phytochemical elements that may be beneficial for influencing illness. The traditional uses of plants have been demonstrated by a revaluation of their efficiency in different places. There are variations in the convention of plant components for lowering glucose level, which are illustrated in Figure 3.

5 Phytoconstituents present in the ethnomedicinal plants

Many of the chemical compounds found naturally in plants that are used to treat diabetes are formed or stimulated by plants (33, 34). Therefore, this review describes numerous phytoconstituents of ethnomedicine plants used by the Himachal Pradesh population to treat diabetes (35). The plants are also used for the development of antioxidant and antimicrobial drugs (36). Researchers have become increasingly interested in medicinal plants over the past few years since secondary metabolites have been identified and their potential to prevent chronic and degenerative diseases has been proven (37). For example, phenolics are well-known secondary metabolites with numerous biological activities, like antioxidant, antidiabetic, antimutagenic, and anti-inflammatory (38). A significant amount of research is being conducted to discover strong anti-diabetic herbal medications

using ethnopharmacological methods such as isolation and identification of active metabolites and their mechanisms of action (39). The chemical structures of major phytoconstituents, as reported in the literature to possess antidiabetic properties, are shown in Figure 4. Various other chemicals present in medicinal plants are mentioned in Table 2.

Documentation of traditional medicinal plants, along with a screening of their biological properties, is a key part of the search for novel drugs to treat drug-resistant pathogens or disorders related to oxidative stress, such as diabetes, in the modern era (40). Certain phytochemicals biological effects, such as antidiabetic, anticancer, antiviral, antimicrobial, antibacterial, and antioxidant activity, have been found to be valuable in the cure of diabetes and other ailments. Numerous phytochemicals and plant extracts confirmed the effectiveness of diabetes (41). The existence of pathogenic organisms or disease-causing processes, such as cancer, diabetes, and inflammatory illnesses, is intimately associated with free radical oxidative (42).

6 Ethnopharmacological research of specific plant species used for the control of diabetes

As mentioned in Table 2, the therapeutic benefits of plants are related to the existence of many bioactive compounds that are a good start for diabetes (43). The traditional uses of plants and the effect of different plant extract components show antidiabetic activities (44), while, some plants assist in the discovery of compounds that aid in the production of synthetic drugs to treat diabetes (45). For the practical use of these plants to treat diabetes, ethnopharmacological studies are required (46). Various *in-vivo* trials have been showing a demand to assess the ethnomedicinal significance of the plant's role in treating diabetes (47). So, Table 3 provides information about various plant species, biochemicals, the dose taken, the experimental model (animal model), compounds as they control hyperglycemia, and their efficiency against diabetes.

7 Conclusion

Long-term use of allopathic drugs has been associated with serious side effects and metabolic complications. The present review highlights the ethnomedicinal diversity of Himachal Pradesh, identifying key antidiabetic plants such as *Syzygium cumini*, *Momordica charantia*, *Tinospora cordifolia*, *Gymnema sylvestre*, *Aegle marmelos*, and *Trigonella foenum-graecum*. Their efficacy is attributed to bioactive compounds including mycaminose, charantin, momordicin, tinosporaside, gymnemic acids, aegeline, and 4-hydroxyisoleucine, which regulate glucose metabolism through insulin secretion, enhanced glucose uptake, and enzyme inhibition. The findings demonstrate that these bioactive compounds regulate glucose metabolism through multiple mechanisms, including enhancement of insulin secretion and

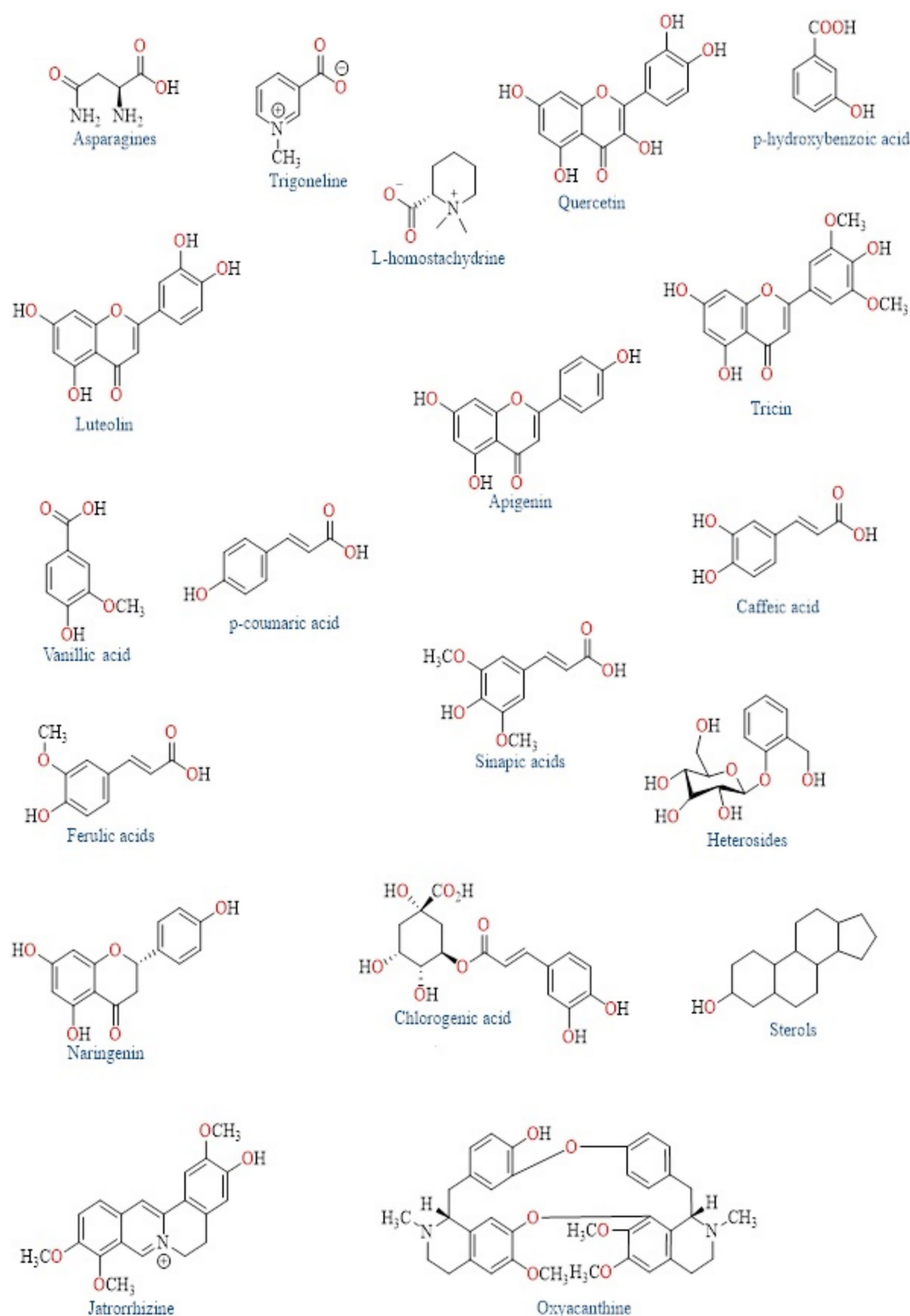


FIGURE 4 (Continued)

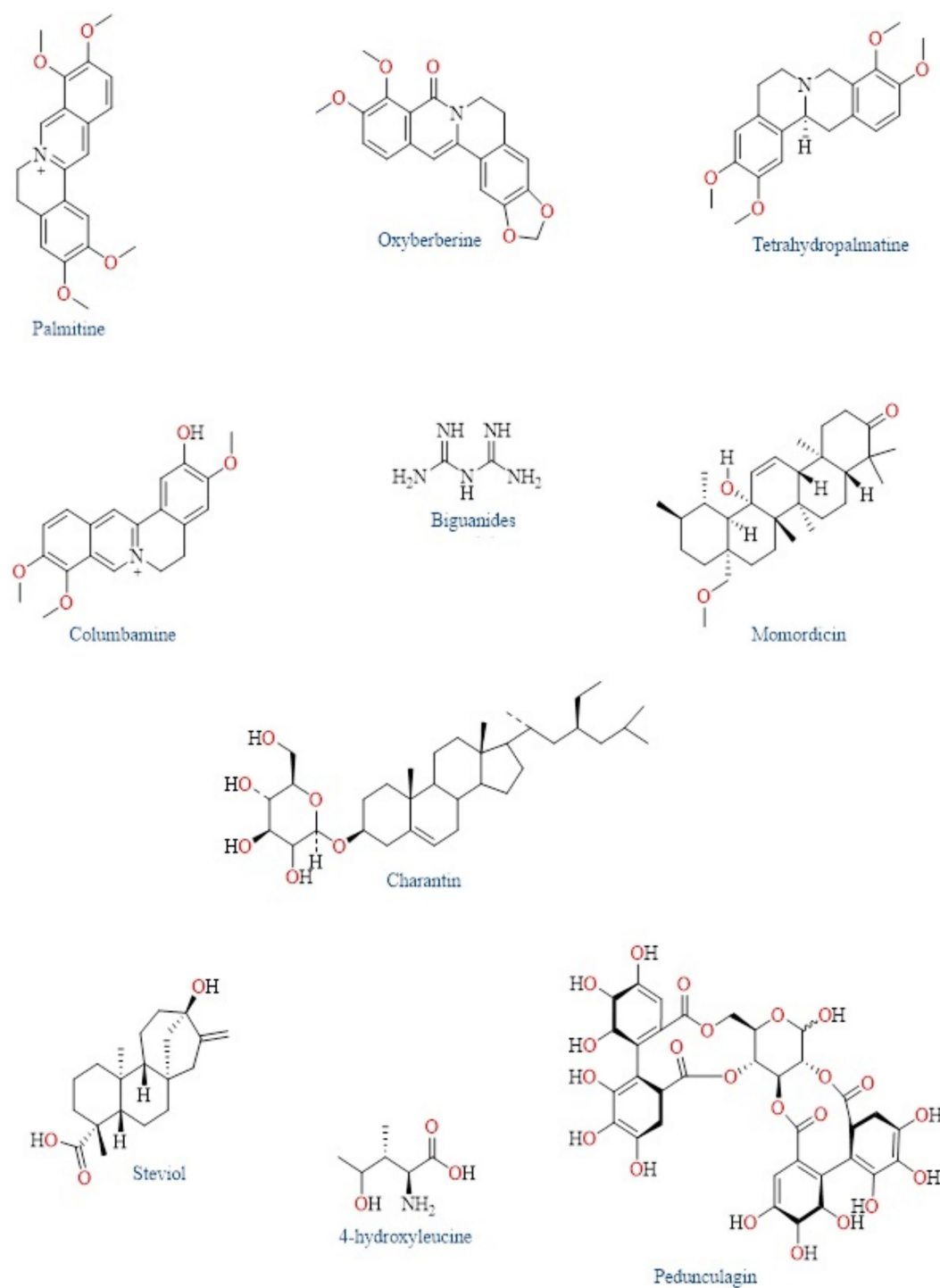


FIGURE 4 (Continued)

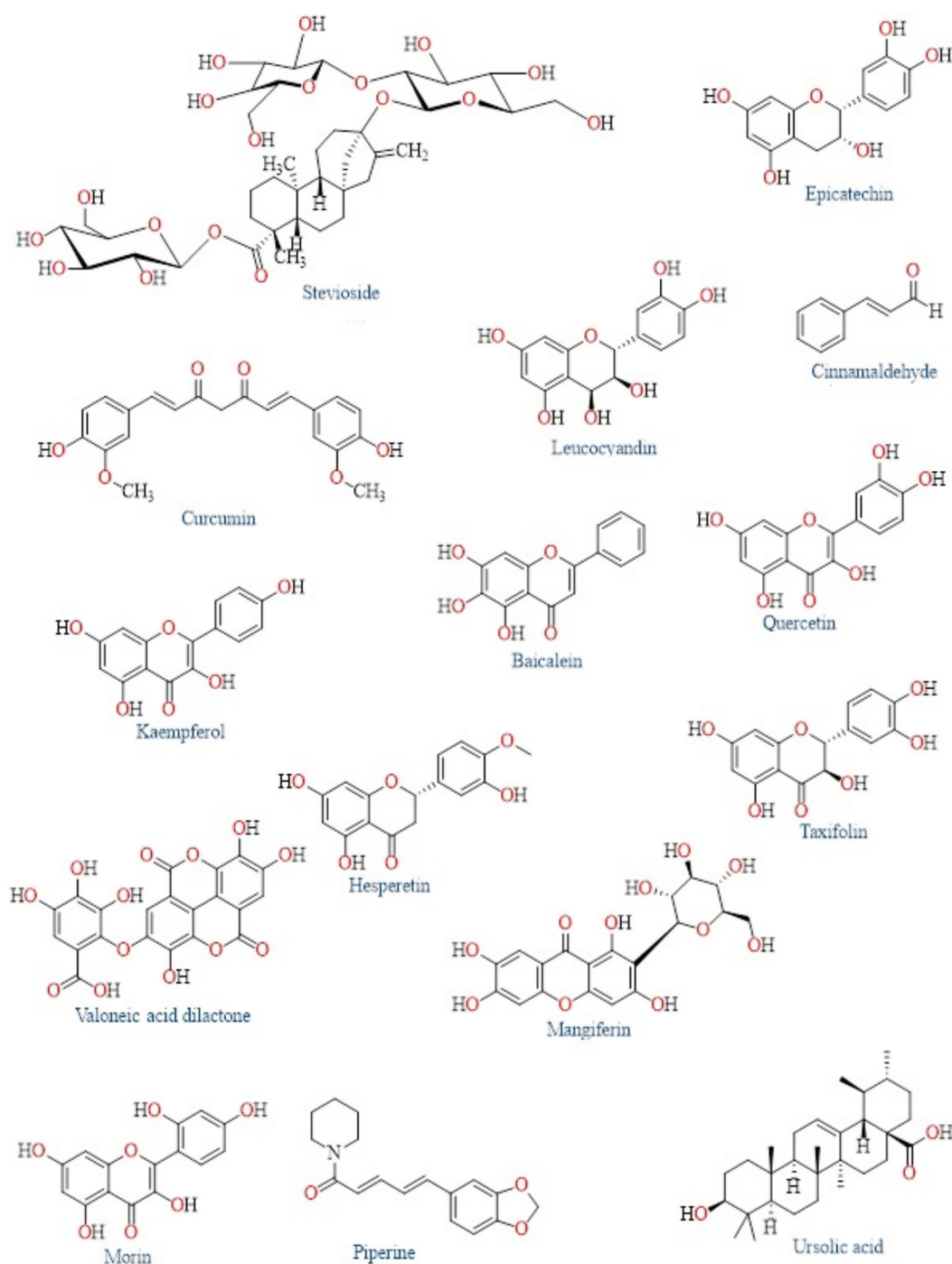


FIGURE 4

Chemical structures of major bioactive phytoconstituents which have antidiabetic activity. This structural diversity highlights the potential of plant-derived molecules as promising candidates for the development of novel antidiabetic therapeutics.

reduction of intestinal glucose absorption. The *in-vivo* studies presented in this review show that many plants, including *Asparagus racemosus*, *Acacia nilotica*, *Aegle marmelos*, *Allium sativum*, *Gymnema sylvestre*, and *Tinospora cordifolia*, have high antidiabetic potential when tested in models of diabetes induced by streptozotocin and alloxan with dosing concentrations of around 100–400 mg/kg, mostly due to bioactive compounds such as flavonoids, alkaloids, phenols, and saponins. Unlike previous descriptive studies, this review integrates ethnomedicinal

knowledge with phytochemical and pharmacological evidence, providing a structured foundation for herbal drug discovery. It is essential as this type of information links conventional ethnomedicinal data with current phytochemical and pharmacological information, providing a systematic framework for herbal medicine research. This paves the way for the discovery of potential bioactive substances and guides researchers toward conducting further research in areas where there are gaps in information. Furthermore, this study identifies key research gaps,

TABLE 2 Main phytochemicals present in ethnomedicinal plants with hypoglycemic or anti-diabetic activity.

Plant name	Phytochemical constituents	References
<i>Medicago sativa</i> L.	Asparagines, trigoneline, stachydrine, L-homostachydrine, carotene, phenolic compounds, vanillic acid and p-hydroxybenzoic acid, heterosides, p-coumaric, naringenin, tannic, ferulic, salicylic, sinapic, caffeic and chlorogenic, hesperetin	(72)
<i>Acacia nilotica</i>	Flavonoids, phenols, saponins, steroids, tannins	(73)
<i>Allium cepa</i> L.	Allyl propyldisulfide as well as S-methyl cysteine sulfoxide	(74)
<i>Allium sativum</i> L.	S-allyl cysteine sulfoxide	(75)
<i>Aloe vera</i> (L.) Burm. f.	Pseudoprotinosaponin and protinosaponins	(76)
<i>Aegle marmelos</i>	Aegeline	(77)
<i>Bacopa monnieri</i> (L.) Wettst.	Herpestine, brahmine, Bacosine and flavonoids	(78)
<i>Bauhinia variegata</i> L.	Roseoside	(79)
<i>Berberis aristata</i> DC.	Alkaloid, tannins, phytosterols, flavonoid, volatile oils	(80)
<i>Berberis aristata</i>	Berberine phenoxide, ketoberberine benzoate A, ketoberberine benzoate B Root—oxyberberine, columbamine, oxyacanthine, berbamine, palmitine, Berberine, jatrorrhizine, tetrahydropalmatine,	(81)
<i>Catharanthus roseus</i>	Catharanthine, vindoline, vindolinine	(82)
<i>Cinnamomum cassia</i> (L.) J. Presl	Cinnamic acid and cinnamaldehyde	(83)
<i>Curcuma longa</i> L.	Curcumin	(84)
<i>Curcuma longa</i>	Curcuminoids, bisdemethoxycurcumin	(43)
<i>Curcuma longa</i>	Turmerin	(85)
<i>Erigeron annuus</i>	Caffeic acid, flavonoids, tannins triterpenoids, saponins, sterols, alkaloids	(86)
<i>Erigeron annuus</i>	Erigeroflavanone	(87)
<i>Erigeron annuus</i>	3,5-Di-O-caffeoylquinic acid	(88)
<i>Fagopyrum esculentum</i>	Rutin and quercetin	(61)
<i>Ficus bengalensis</i>	Leucocyanidin 3-O-beta-d-galactosyl cellobioside as well as leucopelargonidin-3-O-alpha-L rhamnoside	(77)
<i>Ficus racemosa</i>	Kaempferol, naringenin, baicalein, quercetin	(43)
<i>Galega officinalis</i>	Biguanides	(89)
<i>Galega officinalis</i> L.	Quercetin and gaultherin	(58)
<i>Gymnema sylvestre</i> (Retz.) R.Br. ex Sm.	Dihydroxy gymnemic triacetate, Gymnemosides A, B, gymnemic acid V, gymnemic acids I–IV and gymnemasaponin	(90)
<i>Jasminum officinale</i>	Ascorbic acid alkaloids, resin, carbohydrates, coumarins, flavonoids salicylic acid, saponins, tannins, and terpenoids	(65)
<i>Mangifera indica</i>	Mangiferin	(91)
<i>Mangifera indica</i>	C-glucosylxanthone mangiferin	(92)
<i>Momordica angolensis</i> R. Fern.	Momordicin, charantin, and galactose-binding lectin	(93)
<i>Morus alba</i>	Moracin M, steppogenin-4'-Ob-D-glucoside and mullberoside	(94)
<i>Morus alba</i>	Moracin M, steppogenin-4'-O-β-D-glucoside and mullberoside A	(95)
<i>Nelumbo nucifera</i> Gaertn.	Nuciferine	(96)
<i>Ocimum sanctum</i> L.	Ursolic acid, ursolic acid stearyl glucoside	(97)
<i>Oroxylum indicum</i> (L.) Kurz	Baicalein	(98)
<i>Piper longum</i>	Piperine	(99)
<i>Piper sarmentosum</i> Roxb.	Quercetin, naringenin, hesperetin and taxifolin/dihydroquercetin	(84)
<i>Polygala senega</i> L.	Z-senegins II and III, IV, esenegasaponin C and Z-senegasaponin C	(100)
<i>Psidium guajava</i> L.	Flavonoids, triterpenoids, tannins, saponins, sterols, alkaloids	(101)

(Continued)

TABLE 2 (Continued)

Plant name	Phytochemical constituents	References
<i>Psidium guajava</i>	Strictinin, isostrictinin and pedunculagin	(102)
<i>Psidium guajava</i>	Morin	(103)
<i>Psidium guajava</i>	Strictinin and isostrictinin and pedunculagin	(104)
<i>Pterocarpus marsupium</i> Roxb.	Epicatechin	(105)
<i>Punica granatum</i>	Punicalagin, valoneic acid dilactone, anthocyanin, phenolic and non-phenolic acids, Glutenins and tannins	(106)
<i>Punica granatum</i>	Tannin (cid)	(107)
<i>Solanum torvum</i> Sw.	Rutin, caffeic acid, gallic acid and catechi	(108)
<i>Stephania tetrandra</i> S. Moore	Tetrandrine 2'-N- β -oxide tetrandrine 2'-N- α -oxide, tetrandrine 2-N- β -oxide, fangchinoline 2'-N- α -oxide, 2'-N-norfangchinoline, and 2'-N-methyltetrandrinium chloride	(109)
<i>Stevia achalensis</i> Hieron.	Stevioside, steviol	(110)
<i>Swertia chirayita</i>	Swertchiri	(111)
<i>Syzygium cumini</i>	Mycaminose	(112)
<i>Tectona grandis</i> L.f.	3,8-dihydroxy-2-methyl anthraquinone	(13)
<i>Teucrium polium</i> L.	Apigenin	(113)
<i>Tinospora cordifolia</i> (Willd.) Miers	Tinosporaside	(114)
<i>Trigonelia foenumgraecum</i>	Trigonelline and nicotinic acid	(50)
<i>Trigonella foenumgraecum</i>	4-hydroxyleucine and hydroxyisoleucine	(115)
<i>Triticum aestivum</i> L.	Polysaccharide	(116)

including the need for molecular docking studies, target validation, and advanced *in-vivo* investigations to support clinical translation.

Author contributions

MT: Conceptualization, Formal analysis, Writing – original draft, Writing – review & editing. SV: Conceptualization, Formal analysis, Writing – review & editing. BT: Formal analysis, Writing – review & editing. DU: Formal analysis, Writing – review & editing. TS: Formal analysis, Writing – review & editing. BK: Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing. EH: Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing. MZ: Formal analysis, Writing – review & editing. AS: Methodology, Software, Supervision, Validation, Writing – original draft, Writing – review & editing. AA: Funding acquisition, Project administration, Resources, Supervision, Writing – review & editing.

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TABLE 3 In-vivo data of most common ethnomedicinal plants in Himachal Pradesh used for the treatment of diabetes.

Plant species	Major phytochemicals	Model used	Induction of diabetes	Dose	References
<i>Asparagus racemosus</i>	Alkaloid, flavonoid and phenols	Wistar rats	Streptozotocin (STZ)	200, 400	(117)
<i>Acacia arabica</i>	Polyphenols, tannins, and flavonoids	Rat	STZ	100, 200	(118)
<i>Acacia nilotica</i> (L.)	Alkaloids	Rats	STZ	100	(119)
<i>Acacia nilotica</i> (L.) Delile	Flavonoid, phenols, alkaloids	Rats	Alloxan	50	(120)
<i>Achyranthes aspera</i>	Alkaloid, flavonoids, phenols	Rats	STZ	1,000	(121)
<i>Aegle marmelose</i>	Alkaloid, flavonoids, phenols	Rats	STZ	125, 250	(122)
<i>Azzeria africana</i>	Alkaloids, flavonoids, phenols, tannins, saponins, terpenoids	Rats	STZ	100, 200	(123)
<i>Allium cepa</i>	Flavonoids, phenols	Rats	STZ-	100	(124)
<i>Allium cepa</i> L.	Phenolic compounds polysaccharides, saponins	Rats	STZ	500	(125)
<i>Allium sativum</i>	Flavonoids, phenols	Rats	STZ	100	(126)
<i>Allium sativum</i> L.	Flavonoids, alkaloids, polyphenols,	Rats and mice	STZ and alloxan	100	(127)
<i>Aloe barbadensis</i> Miller	Polyphenols, tannins, flavonoids	Rats	STZ	300, 500	(128)
<i>Aloe vera</i> L.	Polyphenols, tannins, flavonoids	Rats	STZ	100, 200	(129)
<i>Amaranthus caudatus</i>	Flavonoids phenols	Rats	STZ	200, 400	(130)
<i>Amaranthus esculantus</i>	Tannins, alkaloids, flavonoids, phenols, saponins terpenoids	Rats	STZ	100, 200	(131)
<i>Andrographis paniculata</i>	Alkaloids, flavonoids, phenols, tannins, saponins terpenoids	Rats	Alloxan	100, 200	(132)
<i>Azadirachta indica</i> A. Juss	Flavonoid, tannins, phenols, alkaloids	Albino wistar rats	Alloxan	200, 400, 800	(133)
<i>Bauhinia variegata</i>	Flavonoids phenols	Rats	Alloxan and STZ	300, 400, 500	(80)
<i>Berberis aristata</i> DC	Flavonoid, tannins, phenols, alkaloids	Male albino Wistar rats	Alloxan	200	(57)
<i>Berberis vulgaris</i> L.	Tannins, alkaloids, saponins, phytosteroidsanthraquinones	Male Wistar rats	STZ	250	(134)
<i>Cajanus cajan</i> L.	Phenols	Swiss albino mice	Alloxan	200, 400	(135)
<i>Cassia auriculata</i>	Alkaloids, flavonoids, phenols, tannins, saponins terpenoids	Rats	STZ	400	(5)
<i>Cassia fistula</i> Linn	Alkaloids, glycosides, flavones, tannins, terpenes, sterols, saponins	Rats	STZ	200, 400	(134)
<i>Curcuma aromatica</i>	Phenols, flavonoids	Wister albino rats	STZ	200	(136)
<i>Curcuma longa</i>	Polyphenols, tannins, flavonoids	Albino rats	Alloxan	400	(137)
<i>Curcuma longa</i>	Alkaloids, glycosides, saponins, steroids, flavonoids	Mice	Alloxan	100, 200	(138)
<i>Cymbopogon citratus</i> (DC.) Stapf	Alkaloids, flavonoids, phenols	Rats	STZ	500	(119)
<i>Ficus bengalensis</i>	Alkaloids, terpenoids, quinones, flavonoids	Rats	Alloxan	100	(94)
<i>Gymnema sylvestre</i>	Alkaloids, phenols, tannins, saponin	Rats	Alloxan	100, 200, 300	(139)
<i>Juglans regia</i>	Alkaloids, flavonoids, phenols, tannins, saponins, terpenoids	Rat	STZ	250, 500	(138)
<i>Mangifera indica</i>	Flavonoid, phenols	Rats	STZ	100	(138)
<i>Nelumbo nucifera</i>	Flavonoids, phenols	Rats	STZ	100	(140)

(Continued)

TABLE 3 (Continued)

Plant species	Major phytochemicals	Model used	Induction of diabetes	Dose	References
<i>Ocimum basilicum</i> L.	Flavonoids, alkaloids, polyphenols,	Rats	STZ	200, 250	(141)
<i>Ocimum sanctum</i>	Polyphenols, tannins, flavonoids	Male albino Wistar rats	Alloxan	200	(142)
<i>Ocimum sanctum</i> L.	Saponin, flavonoids, triterpenoids, tannins	Rats	STZ	100, 200	(143)
<i>Picrorhiza kurroa</i> Royle	Cucurbitacin, phenols, flavonoids	Male Wistar rats	STZ	100, 200	(144)
<i>Polygala senega</i>	Flavonoids, alkaloids, polyphenols,	Mice	STZ	50, 100	(145)
<i>Swertia chirayita</i>	Flavonoids, terpenoids	Rats	STZ	(100, 200)	(30)
<i>Swietenia macrophylla</i>	Tannins alkaloids, flavonoids, phenols, saponins, terpenoids	Rats	STZ	200, 300	(146)
<i>Syzygium cumini</i>	Flavonoids, phenols	Mice and Rats	STZ	100, 200	(147)
<i>Syzygium cumini</i>	Terpenoids, alkaloids, flavonoids, phenols, tannins, saponins	Rats	STZ	100	(148)
<i>Tectona grandis</i> L.	Alkaloids, glycosides, saponins, steroids, flavonoids	Rats and mice	Alloxan	100	(149)
<i>Tinospora cordifolia</i>	Flavonoids, phenols	Rats	Alloxan	100 and 200	(150)
<i>Tinospora cordifolia</i>	Alkaloids, terpenoids, quinones, flavonoids	Rats	STZ	250	(151)
<i>Tinospora cordifolia</i>	Alkaloids, phenols, tannins, saponin	Rats	STZ	200, 400	(150)
<i>Withania somnifera</i>	Flavonoids, alkaloids, polyphenols,	Rats	STZ	100, 200	(152)
<i>Withania somnifera</i> L.	Flavonoids	Male albino Wistar rats	Alloxan	100, 200	(153)
<i>Zingiber officinale</i>	Tannins, alkaloids, flavonoids, phenols, saponins, terpenoids		STZ	100	(154)

References

- Chauhan S, Kaur A, Vyas M, Khatik GL. Comparison of antidiabetic and antioxidant activity of wild and cultivated variety of *Rauwolfia serpentina*. *Asian J Pharm Clin Res.* (2017) 10:404–6. doi: 10.22159/ajpcr.2017.v10i12.21287
- Rani S, Singh G, Sood N. Comparison of intensity and percolation of traditional knowledge of *Calotropis procera* and *Calotropis gigantea* in rural area of Kurukshetra district, Haryana-a survey. *J Med Plants Stud.* (2017) 5:36–8.
- Boktapa NR, Sharma AK. Wild medicinal plants used by local communities of Manali, Himachal Pradesh, India. *Ethnobot Leaflet.* (2010) 14:259–67.
- Gulati AK, Pandey S, Gupta S, Gupta K. A Guide to National Parks and Wildlife Sanctuaries of Himachal Pradesh. Shimla: Wildlife Wing, Forest Department (2004).
- Gupta S, Sidhu MC, Ahluwalia AS. Plant-based remedies for the management of diabetes. *Curr Bot.* (2017) 8:34–40. doi: 10.19071/cb.2017.v8.3169
- Zhang FS, Li HJ, Yu X, Song YP, Ren YF, Qian XZ, et al. Global trends and hotspots of type 2 diabetes in children and adolescents: a bibliometric study and visualization analysis. *World J Diabetes.* (2025) 16:96032. doi: 10.4239/wjd.v16.i1.96032
- Moorthy R, Prabhu KM, Murthy PS. Anti-hyperglycemic compound (GII) from fenugreek (*Trigonella foenum-graecum* Linn.) seeds, its purification and effect in diabetes mellitus. *Indian J Exp Biol.* (2010) 48:1111–8.
- Abu-Odeh AM, Talib WH. Middle East medicinal plants in the treatment of diabetes: a review. *Molecules.* (2021) 26:742. doi: 10.3390/molecules26030742
- Bharadwaj J, Seth MK. Medicinal plant resources of Bilaspur, Hamirpur and Una districts of Himachal Pradesh: an ethnobotanical enumeration. *J Med Plants Stud.* (2017) 5:99–110.
- Rotenstein LS, Kozak BM, Shivers JP, Yarchoan M, Close J, Close KL. The ideal diabetes therapy: what will it look like? How close are we? *Clin Diabetes.* (2012) 30:44–53. doi: 10.2337/diaclin.30.2.44
- Surya S, Salam AD, Tomy DV, Carla B, Kumar RA, Sunil C. Diabetes mellitus and medicinal plants-a review. *Asian Pac J Trop Dis.* (2014) 4:337–47. doi: 10.1016/S2222-1808(14)60585-5
- Pal DK, Dutt B, Varun Attri RD. Studies on important medicinal plants of mid Himalayan region of Himachal Pradesh. *Int J Pharm Innov.* (2020) 9:158–75.
- Shukla N, Kumar M, Akanksha Ahmad G, Rahuja N, Singh AB, Maurya R. Tectone, a new antihyperglycemic anthraquinone from *Tectona grandis* leaves. *Nat Prod Commun.* (2010) 5:427–30. doi: 10.1177/1934578X1000500318
- Ahmad H, Gupta P, Tufchi N, Pant K, Kumar N. In silico modelling and docking of protein of *Candida glabrata* with FDA-approved drugs: a drug repurposing approach. *Asian J Pharm Clin Res.* (2016):148–53.
- Jeevanandam J, Kiew SF, Boakye-Ansah S, Lau SY, Barhoum A, Danquah MK, et al. Green approaches for the synthesis of metal and metal oxide nanoparticles using microbial and plant extracts. *Nanoscale.* (2022) 14:2534–71. doi: 10.1039/D1NR01844F
- Wallace TM, Matthews DR. Poor glycaemic control in type 2 diabetes: a conspiracy of disease, suboptimal therapy, and attitude. *QJM.* (2000) 93:369–74. doi: 10.1093/qjmed/93.6.369
- Sharma K, Verma R, Kumar D, Nepovimova E, Kuča K, Kumar A, et al. Ethnomedicinal plants used for the treatment of neurodegenerative diseases in Himachal Pradesh, India in Western Himalaya. *J Ethnopharmacol.* (2022) 293:115318. doi: 10.1016/j.jep.2022.115318
- Rahman MM, Islam MR, Shohag S, Hossain ME, Rahaman MS, Islam F, et al. The multifunctional role of herbal products in the management of diabetes and obesity: a comprehensive review. *Molecules.* (2022) 27:1713. doi: 10.3390/molecules27051713
- Brown AE, Walker M. Genetics of insulin resistance and the metabolic syndrome. *Curr Cardiol Rep.* (2016) 18:75–8. doi: 10.1007/s11886-016-0755-4
- Chakraborty AJ, Uddin TM, Zidan M, Redwan BM, Mitra S, Das R, et al. *Allium cepa*: a treasure of bioactive phytochemicals with prospective health benefits. *Evid Based Complement Altern Med.* (2022) 2022:4586318. doi: 10.1155/2022/4586318
- Xu L, Li Y, Dai Y, Peng J. Natural products for the treatment of type 2 diabetes mellitus: pharmacology and mechanisms. *Pharmacol Res.* (2018) 130:451–65. doi: 10.1016/j.phrs.2018.01.015
- Kazi S. Use of traditional plants in diabetes mellitus. *Int J Pharm Sci.* (2014) 4:283–9.

23. Kar S, Roy K. QSAR of phytochemicals for the design of better drugs. *Expert Opin Drug Discov.* (2012) 7:877–902. doi: 10.1517/17460441.2012.716420
24. Wais M, Nazish I, Samad A, Beg S, Abusufyan S, Ajaz Ajaz S, et al. Herbal drugs for diabetic treatment: an updated review of patents. *Recent Pat Antiinfect Drug Discov.* (2012) 7:53–9. doi: 10.2174/157489112799829701
25. Perrier S, Darakhshan F, Hajdudch E. IL-1 receptor antagonist in metabolic diseases: Dr Jekyll or Mr Hyde? *FEBS Lett.* (2006) 580:6289–94. doi: 10.1016/j.febslet.2006.10.061
26. Khalaf SA, Mohsin IH, Abd Mohammed Z, Ahmed SS. Toll-like receptors (TLRs) and their role in diabetic mellitus disease: a review. *Yemeni J Med Sci.* (2025) 19:79–93. doi: 10.20428/yjms.v19i7.3013
27. Ruiz PJ, Masliah E, Doherty TA, Quach A, Firestein GS. Cardiac death in a patient with adult-onset still's disease treated with the interleukin 1 receptor inhibitor anakinra. *Ann Rheum Dis.* (2007) 66:422–3. doi: 10.1136/ard.2006.060541
28. Trasca DM, Dop D, Stoica GA, Adrian NS, Carmen NE, Văruț RM, et al. The antidiabetic activity of wild-growing and cultivated medicinal plants used in Romania for diabetes mellitus management: a phytochemical and pharmacological review. *J Pharm.* (2025) 18:1035. doi: 10.3390/ph18071035
29. Lanza K, Dias R, dos Santos Oliveira RM, Belotto L, Miranda AS, Simões e Silva AC. Renin-angiotensin system in central nervous system diseases and its interaction with COVID-19. *Curr Med Chem.* (2021) 28:5733–87. doi: 10.2174/0929867328666210212101854
30. Dey P, Singh J, Suluvoy JK, Dilip KJ, Nayak J. Utilization of *Swertia chirayita* plant extracts for management of diabetes and associated disorders: present status, prospects and limitations. *Nat Prod Bioprospecting.* (2020) 10:431–43. doi: 10.1007/s13659-020-00277-7
31. Kooti W, Farokhipour M, Asadzadeh Z, Ashtary-Larky D, Asadi-Samani M. The role of medicinal plants in the treatment of diabetes: a systematic review. *Electron Physician.* (2016) 8:1832–42. doi: 10.19082/1832
32. Singhal P. Ethnomedicinal plants used against liver and kidney ailments by the rural population of tehsil Paonta sahib, district Sirmour, Himachal Pradesh (India). *J Med Act Plants.* (2019):33–45. doi: 10.7275/8the-5370
33. Bhat VS, Nasavati DD, Mardikar BR. *Adhatoda vasica*-an ayurvedic medicinal plant. *Indian Drugs.* (1978) 15:6.
34. Matalqah SM, Al-Tawalbeh DM. Medicinal plants potential against diabetes mellitus. *Diabetes.* (2025) 6:39–53.
35. Jaswal S. Ethnobotanical study of wild medicinal plants used by local people of Una district of Himachal Pradesh, India. *Himachal Pradesh Univ J.* (2019) 7:14–26.
36. Gichuru V, Sbrocca I, Molinari M, Tonto TC, Locato V, Cimini S, et al. Exploring the antioxidant and antimicrobial properties of five indigenous Kenyan plants used in traditional medicine. *Sci Rep.* (2025) 15:1459. doi: 10.1038/s41598-024-80883-4
37. Kowalczyk T, Piekarski J, Kowalski M, Del Rosario Garcia H, Merecz-Sadowska A, Amaro C, et al. Therapeutic potential of *Pistacia* extracts in the prevention and treatment of oxidative stress-related diseases: the role of nanotechnology in improving bioavailability. *Food Rev Int.* (2025) 42:2248–308. doi: 10.1080/87559129.2025.2544967
38. Shawky EM, Hamdy R, Elgindi MR, Baky MH. UPLC-HRMS-MS profiling of *Ludwigia ascendens* subsp. diffusa aerial parts and investigation of the anti-inflammatory effect. *Sci Rep.* (2025) 15:19718. doi: 10.1038/s41598-025-05183-x
39. Mutha RE, Kalaskar M, Khan ZG. Modern analytical techniques for quality control and chemical identification of phytochemicals. *J Pharmacogn Phytochem.* (2025) 191:280–300. doi: 10.1002/9781394203680.ch09
40. Raghuvanshi D, Dhalaria R, Sharma A, Kumar D, Kumar H, Valis M, et al. Ethnomedicinal plants traditionally used for the treatment of jaundice (icterus) in Himachal Pradesh in Western Himalaya—a review. *Plants.* (2021) 10:232. doi: 10.3390/plants10020232
41. Khan S, Bhanot A, Bhandari DD. Assessing the efficacy of methanol extracts of *Ocimum sanctum* Linn. and *Ocimum basilicum* Linn. in diabetic neuropathy. *Scr Med.* (2025) 56:1–13. doi: 10.5937/scriptamed56-52822
42. Dixit V, Chaubey KK, Dayal D, Chole PB, Bachheti RK, Gupta PC, et al. Natural products in aging: cellular mechanisms and emerging therapeutics for age-related disorders. *J Aging Res.* (2025) 2025:6868732. doi: 10.1155/jare/6868732
43. Kalaycioglu Z, Gazioglu I, Erim FB. Comparison of antioxidant, anticholinesterase, and antidiabetic activities of three curcuminoids isolated from *Curcuma longa* L. *Nat Prod Res.* (2017) 31:2914–7. doi: 10.1080/14786419.2017.1299727
44. Shantabi L, Jagetia GC, Vabeiryureilai M, Lalrinzuali K. Phytochemical screening of certain medicinal plants of Mizoram, India, and their folklore use. *J Biodiver Bioprospect J Develop.* (2014) 1:4. doi: 10.4172/2376-0214.1000136
45. Gupta N, Bano U, Kimta N, Khan A, Nepovimova E, Alomar SY, et al. Efficacy of antidiabetic plants available in Himachal Pradesh in management of diabetes: a comprehensive review. *Phytochem Rev.* (2025) 24:739–71. doi: 10.1007/s11101-024-09971-7
46. Tewari D, Mocan A, Parvanov ED, Sah AN, Nabavi SM, Huminiecki L, et al. Ethnopharmacological approaches for therapy of jaundice: part II. Highly used plant species from Acanthaceae, Euphorbiaceae, Asteraceae, Combretaceae, and Fabaceae families. *Front Pharmacol.* (2017) 8:519. doi: 10.3389/fphar.2017.00519
47. Banaszak M, Górna I, Przyslawski J. Non-pharmacological treatments for insulin resistance: effective intervention of plant-based diets—a critical review. *Nutrients.* (2022) 14:1400. doi: 10.3390/nu14071400
48. Kumar N, Jakhar AK, Choyal R. Traditional uses of some medicinal plants of Hamirpur district of Himachal Pradesh for the treatment of diabetes. *Int J Adv Res.* (2014) 2:131–9.
49. Jishtu V, Moran A, Ibrahim M, Ahmad Z. Quantitative study of the Indian ethnobotanical medicinal plant resources in the remote Zaskar valley of Ladakh. *Ethnobot Res Appl.* (2025) 31:1–28. doi: 10.32859/era.31.12.1-28
50. Rawat DS, Kharwal AD. Traditional phyto-remedies for gynecological complaints in Balh valley™, district Mandi (Himachal Pradesh), India. *Life Sci Leaflet.* (2011) 16:546–50.
51. Kumar G, Chander H. Traditional usage of ethno-medicinal plants of Sikandra Hill range in Mandi district of Himachal Pradesh, India. *Asian J Adv Basic Sci.* (2019) 7:42–9. doi: 10.33980/ajabs.2019.v07i02.006
52. Rana M, Sharma S. Commonly used medicinal plants in tehsil Pachhad, district Sirmour, Himachal Pradesh. *Environ Dev Sustain.* (2016) 4:34–8.
53. Thakur M, Asrani RK, Thakur S, Sharma PK, Patil RD, Lal B, et al. Observations on traditional usage of ethnomedicinal plants in humans and animals of Kangra and Chamba districts of Himachal Pradesh in North-Western Himalaya, India. *J Ethnopharmacol.* (2016) 191:280–300. doi: 10.1016/j.jep.2016.06.033
54. Nagarkoti K, Kanyal J, Prakash O, Kumar R, Rawat DS, Pant AK. *Ajuga* L.: a systematic review on chemical composition, phytopharmacological and biological potential. *Curr Bioact Compd.* (2021) 17:11–37. doi: 10.2174/1573407216999210101230234
55. Pundir A, Devi KB, Prakash S, Puri S, Thakur M, Rathour S, et al. Therapeutic uses of wild plant species used by rural inhabitants of Kangra in the western Himalayan region. *S Afr J Bot.* (2022) 148:415–36. doi: 10.1016/j.sajb.2022.05.004
56. Kumar S, Singh V, Saroha J. Geospatial technology for sustainable development: a strategic framework for Sarbari Khad watershed of Himachal Pradesh. *Int J Health Sci.* (2022) 6:12282–92. doi: 10.53730/ijhs.v6n52.8258
57. Singh J, Kakkar P. Antihyperglycemic and antioxidant effect of *Berberis aristata* root extract and its role in regulating carbohydrate metabolism in diabetic rats. *J Ethnopharmacol.* (2009) 123:22–6. doi: 10.1016/j.jep.2009.02.038
58. Singh KJ, Thakur AK. Medicinal plants of the Shimla Hills, Himachal Pradesh: a survey. *Int J Herb Med.* (2014) 2:118–27.
59. Rana D, Bhatt A, Lal B, Parkash O, Kumar A, Uniyal SK. Use of medicinal plants for treating different ailments by the indigenous people of Churah subdivision of district Chamba, Himachal Pradesh, India. *Environ Dev Sustain.* (2021) 23:1162–241. doi: 10.1007/s10668-020-00617-0
60. Singh L, Nandi SK, Bhatt ID, Bisht AK. "Inventorization of ecology, ethnobotany, and conservation status of *Dactylorhiza hatagirea*: problems, progress, and prospects". In: Jha S and Halder M, editors. *Medicinal Plants: Biodiversity, Biotechnology and Conservation. Sustainable Development and Biodiversity.* Singapore: Springer (2023). p. 307–25.
61. Singh J, Singh J, Kumar N, Jishtu V, Sharma S, Dhupper R. Ethno-medicinal plants used by indigenous people of Kanda range, Chopal forest division, Himachal Pradesh. *World J Pharm Pharmaceut Sci.* (2017) 7:697–710. doi: 10.20959/wjpps20181-10709
62. Ratan P, Kothiyal P. *Fagopyrum esculentum* Moench (common buckwheat) edible plant of Himalayas: a review. *Asian J Pharm.* (2011) 1:426–42. doi: 10.13040/IJPSR.0975-8232.IJP.6(2).39-53
63. Chand R, Kaur R, Kaur A, Kumar V, Nirmala C, Singh AN. Assessment of ethnomedicinal plant diversity of Una and Hamirpur district of Himachal Pradesh, India: an ethno-ecological approach. *Ann Plant Sci.* (2016) 5:1475–90. doi: 10.21746/aps.2016.12.005
64. Kumar G, Kumar V, Thakur K. Some overlooked ethno-medicinal plants of district Bilaspur, Himachal Pradesh (India). *CPUH Res J.* (2018) 3:116–23.
65. Sahu R, Arya V, Joshi R, Kaushik P, Chauhan M. Pharmacological and therapeutic properties of *Jasminum officinale* L.: a review. *Indian J Ecol.* (2022) 49:1122–8. doi: 10.55362/IJE/2022/3640
66. Dhaka K, Mittal A. A review on botanical characteristics, phytochemistry, pharmacology and traditional uses of selected medicinal plants: *Juniperus communis*, *Ficus carica*, *Garcinia indica*. *Int J Creat Res Thoughts.* (2021) 9:61–79.
67. Sharma S, Thakur A, Verma P, Kumari S, Sharma S, Arya V. Ethnomedicinal wisdom among local tribes in Hamirpur valley, Himachal Pradesh, India. *J Med Pharm Allied Sci.* (2012) 2:88–94.
68. Upadhyay D. Ethno-botanical important plants in the parts of Shivalik Hills of Kangra district, Himachal Pradesh. *Int J Sci Res.* (2013) 3:1–4.
69. Chauhan P, Puri S, Thakur M, Rathour S, Sharma AK, Pundir A. A study of wild medicinal plants used in Nargu wildlife sanctuary of district Mandi in Himachal Pradesh, India. *J Appl Pharm Sci.* (2021) 11:135–44. doi: 10.7324/JAPS.2021.110416
70. Dhatwalia J, Kumari A, Guleria I, Kumar Shukla R, Saleh NI, El-Nashar HA, et al. Effect of altitude and harvest year on nutraceutical characteristics of *Rubus ellipticus* fruits. *Front Nutr.* (2024) 11:1419862. doi: 10.3389/fnut.2024.1419862

71. Pundir S, Mahindroo N. *Roylea cinerea* (D. Don) Baillon: ethnomedicinal uses, phytochemistry and pharmacology: a review. *J Ethnopharmacol.* (2019) 232:193–200. doi: 10.1016/j.jep.2018.12.042
72. Bora KS, Sharma A. Phytochemical and pharmacological potential of *Medicago sativa*: a review. *Pharm Biol.* (2011) 49:211–20. doi: 10.3109/13880209.2010.504732
73. Prathapa Reddy M, Shantha TR, Naveen Kumar SP, Rama Rao V, Shiddamallayya N, Dixit AK. Pharmacognostical studies on fruits of *Babbula-acacia nilotica* (L.) Delile. *Int J Herb Med.* (2018) 6:115–20.
74. Kumari K, Mathew BC, Augusti KT. Antidiabetic and hypolipidemic effects of S-methyl cysteine sulfoxide isolated from *Allium cepa* Linn. *Indian J Biochem Biophys.* (1995) 32:49–54.
75. Dong R, Duan YQ, Wang XY, Liu Y, Gao GL. Effect of garlic on peroxidation in rats with diabetes. *Chin J of Public Hygiene.* (2000):605–6.
76. Bnouham M, Ziyat A, Mekhfi H, Tahri A, Legssyer A. Medicinal plants with potential antidiabetic activity—a review of ten years of herbal medicine research (1990–2000). *Dubai Diabetes Endocrinol J.* (2006) 14:1–25. doi: 10.1159/000497588
77. Narender T, Shweta S, Tiwari P, Reddy KP, Khaliq T, Prathipati P, et al. Antihyperglycemic and antidyslipidemic agent from *Aegle marmelos*. *Bioorg Med Chem Lett.* (2007) 17:1808–11. doi: 10.1016/j.bmcl.2006.12.037
78. Mondal S, Bhar K, Mondal P, Panigrahi N, Sahoo SK, Swetha P, et al. In quest of the mysterious holistic vedic herb *Bacopa monnieri* (L.) Pennell. *Pharm Res.* (2023) 15:410–54. doi: 10.5530/pres.15.3.045
79. Frankish N, de Sousa Menezes F, Mills C, Sheridan H. Enhancement of insulin release from the β -cell line INS-1 by an ethanolic extract of *Bauhinia variegata* and its major constituent roseoside. *Planta Med.* (2010) 76:995–7. doi: 10.1055/s-0029-1240868
80. Mittal M, Juyal V, Singh A. Phytochemical, antidiabetic, and cytoprotective properties of *Berberis aristata* DC. Root extracts. *Pharm Crop.* (2012) 3:64–8. doi: 10.2174/2210290601203010064
81. Ahamad J, Naquvi KJ, Ali M, Mir SR. New isoquinoline alkaloids from the stem bark of *Berberis aristata*. *J Indian Chem Soc.* (2014) 53:1237–41.
82. Chattopadhyay RR. A comparative evaluation of some blood sugar lowering agents of plant origin. *J Ethnopharmacol.* (1999) 67:367–72. doi: 10.1016/S0378-8741(99)00095-1
83. Ahmad LA, Crandall JP. Type 2 diabetes prevention: a review. *Clin Diabetes.* (2010) 28:53–9. doi: 10.2337/diaclin.28.2.53
84. Bacanli M, Dilsiz SA, Başaran N, Başaran AA. Effects of phytochemicals against diabetes. *Adv Food Nutr Res.* (2019) 89:209–38. doi: 10.1016/bs.afnr.2019.02.006
85. Lekshmi PC, Arimboor R, Raghu KG, Menon AN. Turmeric, the antioxidant protein from turmeric (*Curcuma longa*) exhibits antihyperglycaemic effects. *Nat Prod Res.* (2012) 26:1654–8. doi: 10.1080/14786419.2011.589386
86. Aijaz F, Shadab M, Akhtar N, Parveen U, Siddiqui MB. *Erigeron bonariensis*: Phytochemistry, allelopathy, and potential for sustainable pest management and healthcare. *Vegetos.* (2025) 11:1–27. doi: 10.1007/s42535-025-01376-x
87. Yoo NH, Jang DS, Yoo JL, Lee YM, Kim YS, Cho JH, et al. Erigeroflavanone, a flavanone derivative from the flowers of *Erigeron annuus* with protein glycation and aldose reductase inhibitory activity. *J Nat Prod.* (2008) 71:713–5. doi: 10.1021/np070489a
88. Jang DS, Yoo NH, Kim NH, Lee YM, Kim CS, Kim J, et al. 3, 5-Di-O-caffeoyl-epiquinic acid from the leaves and stems of *Erigeron annuus* inhibits protein glycation, aldose reductase, and cataractogenesis. *Biol Pharm Bull.* (2010) 33:329–33. doi: 10.1248/bpb.33.329
89. Belwal T, Bisht A, Devkota HP, Ullah H, Khan H, Pandey A, et al. Phytopharmacology and clinical updates of *Berberis* species against diabetes and other metabolic diseases. *Front Pharmacol.* (2020) 11:41. doi: 10.3389/fphar.2020.00041
90. Daisy P, Eliza J, Farook KAMM. A novel dihydroxy gymnemic triacetate isolated from *Gymnema sylvestre* possessing normoglycemic and hypolipidemic activity on STZ-induced diabetic rats. *J Ethnopharmacol.* (2009) 126:339–44. doi: 10.1016/j.jep.2009.08.018
91. Swaroop A, Bagchi M, Moriyama H, Bagchi D. Health benefits of mango (*Mangifera indica* L.) and mangiferin. *Jpn J Med.* (2018) 1:149–54. doi: 10.1016/j.fitote.2009.06.009
92. Muruganandan S, Srinivasan K, Gupta S, Gupta PK, Lal J. Effect of mangiferin on hyperglycemia and atherogenicity in streptozotocin diabetic rats. *J Ethnopharmacol.* (2005) 97:497–501. doi: 10.1016/j.jep.2004.12.010
93. Jain A, Chhajer M, Saluja MS, Dwivedi S, Patel B. Treatment of diabetes with Indian herbs and herbal medicines: a review. *Int J Pharm Life Sci.* (2023) 14:3.
94. Zhang M, Chen M, Zhang HQ, Sun S, Xia B, Wu FH. In vivo hypoglycemic effects of phenolics from the root bark of *Morus alba*. *Fitoterapia.* (2009) 80:475–7. doi: 10.1016/j.fitote.2009.06.009
95. Kadam RA, Dhumal ND, Khyade VB. The mulberry, *Morus alba* (L.): the medicinal herbal source for human health. *Int J Curr Microbiol Appl Sci.* (2019) 8:2941–64. doi: 10.20546/ijcmas.2019.804.341
96. Liu W, Yi DD, Guo JL, Xiang ZX, Deng LF, He L. Nuciferine, extracted from *Nelumbo nucifera* Gaertn, inhibits tumor-promoting effect of nicotine involving Wnt/ β -catenin signaling in non-small cell lung cancer. *J Ethnopharmacol.* (2015) 165:83–93. doi: 10.1016/j.jep.2015.02.015
97. Lee J, Lee HI, Seo KI, Cho HW, Kim MJ, Park EM, et al. Effects of ursolic acid on glucose metabolism, the polyol pathway and dyslipidemia in non-obese type 2 diabetic mice. *Int J Exp Bio.* (2014) 52:683–91.
98. Zaveri M, Khandhar A, Jain S. Quantification of baicalein, chrysin, biochanin-A and ellagic acid in root bark of *Oroxylum indicum* by RP-HPLC with UV detection. *Eurasian J Anal Chem.* (2008) 3:247–57.
99. Meghwal M, Goswami TK. *Piper nigrum* and piperine: an update. *Phytother Res.* (2013) 27:1121–30. doi: 10.1002/ptr.4972
100. Yoshikawa M, Murakami T, Ueno T, Kadoya M, Matsuda H, Yamahara J, et al. E-senegasaponins a and B, Z-senegasaponins a and B, Z-senegin II and III, new type inhibitors of ethanol absorption in rats from senegae radix, the roots of *Polygala senega* L. var *latifolia* Torrey et gray. *Chem Pharm Bull.* (1995) 43:350–2. doi: 10.1248/cpb.43.350
101. Arya V, Thakur N, Kashyap CP. Preliminary phytochemical analysis of the extracts of *Psidium* leaves. *J Pharmacogn Phytochem.* (2012) 1:1–5.
102. Chauhan NS. Important medicinal and aromatic plants of Himachal Pradesh. *Indian For.* (2003) 129:979–98. doi: 10.36808/iff/2003/v129i8/2364
103. Paoli P, Cirri P, Caselli A, Ranaldi F, Bruschi G, Santi A, et al. The insulin-mimetic effect of Morin: a promising molecule in diabetes treatment. *Biochim Biophys Acta Gen Subj.* (2013) 1830:3102–11. doi: 10.1016/j.bbagen.2013.01.017
104. Eidenberger T, Selg M, Krennhuber K. Inhibition of dipeptidyl peptidase activity by flavonol glycosides of guava (*Psidium guajava* L.): a key to the beneficial effects of guava in type II diabetes mellitus. *Fitoterapia.* (2013) 89:74–9. doi: 10.1016/j.fitote.2013.05.015
105. Modak M, Dixit P, Londhe J, Ghaskadbi S, Devasagayam TPA. Indian herbs and herbal drugs used for the treatment of diabetes. *J Clin Biochem Nutr.* (2007) 40:163–73. doi: 10.3164/jcbs.40.163
106. Gharib E, Kouhsari SM. Study of the antidiabetic activity of *Punica granatum* L. fruits aqueous extract on the alloxan-diabetic Wistar rats. *Iran J Pharm Res.* (2019) 18:358–68.
107. Canuti V, Cecchi L, Khatib M, Guerrini L, Mulinacci N, Zannoni B. A new extract from pomegranate (*Punica granatum* L.) by-products as a potential oenological tannin: preliminary characterization and comparison with existing commercial products. *Molecules.* (2020) 25:4460. doi: 10.3390/molecules25194460
108. Gandhi GR, Ignacimuthu S, Paulraj MG. *Solanum torvum* Swartz. fruit containing phenolic compounds shows antidiabetic and antioxidant effects in streptozotocin induced diabetic rats. *Food Chem Toxicol.* (2011) 49:2725–33. doi: 10.1016/j.fct.2011.08.005
109. Tsutsumi T, Kobayashi S, Liu YY, Kontani H. Anti-hyperglycemic effect of fangchinoline isolated from *Stephania tetrandra* Radix in streptozotocin-diabetic mice. *Biol Pharm Bull.* (2003) 26:313–7. doi: 10.1248/bpb.26.313
110. Jeppesen PB, Gregersen S, Alstrup KK, Hermansen K. Stevioside induces antihyperglycaemic, insulinotropic and glucagonostatic effects in vivo: studies in the diabetic Goto-Kakizaki (GK) rats. *Phytomedicine.* (2002) 9:9–14. doi: 10.1078/0944-7113-00081
111. Quazi A, Mohsina FP, Faheem IP, Priya S, Faheem IP, Priya S. In silico ADMET analysis, molecular docking and in vivo anti diabetic activity of polyherbal tea bag formulation in streptozotocin-nicotinamide induced diabetic rats. *Int J Health Sci.* (2022) 6:343–72. doi: 10.53730/ijhs.v6n53.5189
112. Kumar A, Ilavarasan R, Jayachandran T, Deecaraman M, Aravindan P, Padmanabhan N, et al. Anti-diabetic activity of *Syzygium cumini* and its isolated compound against streptozotocin-induced diabetic rats. *Med Plant Res.* (2008) 2:246–9.
113. Mirghazanfari SM, Keshavarz M, Nabavizadeh F, Soltani N, Kamalinejad M. The effect of “*Teucrium polium* L.” extracts on insulin release from in situ isolated perfused rat pancreas in a newly modified isolation method: the role of Ca²⁺ and K⁺ channels. *Iran Biomed J.* (2010) 14:178–85.
114. Maurya R, Wazir V, Tyagi A, Kapil RS. Clerodane diterpenoids from *Tinospora cordifolia*. *Phytochem.* (1995) 38:659–61. doi: 10.1016/0031-9422(94)00686-N
115. Grover JK, Yadav S, Vats V. Medicinal plants of India with anti-diabetic potential. *J Ethnopharmacol.* (2002) 81:81–100. doi: 10.1016/S0378-8741(02)00059-4
116. Lee SH, Lim SW, Lee YM, Lee HS, Kim DK. Polysaccharide isolated from *Triticum aestivum* stimulates insulin release from pancreatic cells via the ATP-sensitive K⁺ channel. *Int J Mol Med.* (2012) 29:913–9. doi: 10.3892/ijmm.2012.905
117. Vadivelan R, Dipanjan M, Umasankar P, Dhanabal SP, Satishkumar MN, Antony S, et al. Hypoglycemic, antioxidant and hypolipidemic activity of *Asparagus racemosus* on streptozotocin-induced diabetic in rats. *J Adv Res.* (2011) 2:179–85.
118. Rasouli H, Yarani R, Pociot F, Popović-Djordjević J. Anti-diabetic potential of plant alkaloids: revisiting current findings and future perspectives. *Pharmacol Res.* (2020) 155:104723. doi: 10.1016/j.phrs.2020.104723
119. Mohan S, Thiagarajan K, Chandrasekaran R, Arul J. In vitro protection of biological macromolecules against oxidative stress and in vivo toxicity evaluation of *Acacia nilotica* (L.) and ethyl gallate in rats. *BMC Complement Altern Med.* (2014) 14:257. doi: 10.1186/1472-6882-14-257
120. Ezuruike UF, Prieto JM. The use of plants in the traditional management of diabetes in Nigeria: pharmacological and toxicological considerations. *J Ethnopharmacol.* (2014) 155:857–924. doi: 10.1016/j.jep.2014.05.055
121. Newman DJ, Cragg GM. Natural products as sources of new drugs over the 30 years from 1981 to 2010. *J Nat Prod.* (2012) 75:311–35. doi: 10.1021/np200906s

122. Wolfender JL, Nuzillard JM, Van Der Hooft JJ, Renault JH, Bertrand S. Accelerating metabolite identification in natural product research: toward an ideal combination of liquid chromatography–high-resolution tandem mass spectrometry and NMR profiling, in silico databases, and chemometrics. *Anal Chem.* (2018) 91:704–42. doi: 10.1021/acs.analchem.8b05112
123. Oyedemi SO, Adewusi EA, Aiyegoro OA, Akinpelu DA. Antidiabetic and haematological effect of aqueous extract of stem bark of *Azela africana* (Smith) on streptozotocin-induced diabetic Wistar rats. *Asian Pac J Trop Biomed.* (2011) 1:353–8. doi: 10.1016/S2221-1691(11)60079-8
124. Gholamhosini B, Khaki Ahmadi-Ashtiani HR, Rezazadeh S, Rastegar H, Fathiazad F, Ghanbari M. Treatment effects of onion on spermatogenesis in streptozotocin-induced diabetic rat. *J Med Plants.* (2009) 8:153–61.
125. Zhao XX, Lin FJ, Li H, Li HB, Wu DT, Geng F, et al. Recent advances in bioactive compounds, health functions, and safety concerns of onion (*Allium cepa* L.). *Front Nutr.* (2021) 5:1–23. doi: 10.3389/fnut.2021.66980
126. Raju TN, Kanth VR, Lavanya K. Effect of methanolic extract of *Allium sativum* (AS) in delaying cataract in STZ-induced diabetic rats. *J Ocul Biol Dis Infor.* (2008) 1:46–54. doi: 10.1007/s12177-008-9003-5
127. Londhe VP, Gavasane AT, Nipate SS, Bandawane DD, Chaudhari PD. Role of garlic (*Allium sativum*) in various diseases: an overview. *Angiogenesis.* (2011) 12:129–34.
128. Yadav RNS, Agarwala M. Phytochemical analysis of some medicinal plants. *J Phytol.* (2011) 3:10–4.
129. Haghani F, Arabnezhad MR, Mohammadi S, Ghaffarian-Bahraman A. Aloe vera and streptozotocin-induced diabetes mellitus. *Rev Bras.* (2022) 32:174–87. doi: 10.1007/s43450-022-00231-3
130. Girija K, Lakshman K, Udaya C, Sachi GS, Divya T. Anti-diabetic and anti-cholesterolemic activity of methanol extracts of three species of *Amaranthus*. *Asian Pac J Trop Biomed.* (2011) 1:133–8. doi: 10.1016/S2221-1691(11)60011-7
131. Olabiya FA. *Hepato-Renal, Cardiac and Reproductive Effects of Phyllanthus amarus Leaf Extract in Streptozotocin-Induced Diabetic Male Wistar Rats*. Cape Town: Cape Peninsula University of Technology (2020).
132. Patel DK, Kumar R, Laloo D, Hemalatha S. Diabetes mellitus: an overview on its pharmacological aspects and reported medicinal plants having antidiabetic activity. *Asian Pac J Trop Biomed.* (2012) 2:411–20. doi: 10.1016/S2221-1691(12)60067-7
133. Patil P, Patil S, Mane A, Verma S. Antidiabetic activity of alcoholic extract of neem (*Azadirachta indica*) root bark. *Natl J Physiol Pharm Pharmacol.* (2013) 3:142–6. doi: 10.5455/njppp.2013.3134-138
134. Meliani N, Dib MEA, Allali H, Tabti B. Hypoglycaemic effect of *Berberis vulgaris* L. in normal and streptozotocin-induced diabetic rats. *Asian Pac J Trop Biomed.* (2011) 1:468–71. doi: 10.1016/S2221(11)60102-2
135. Nahar L, Nasrin F, Zahan R, Haque A, Haque E, Mosaddik A. Comparative study of antidiabetic activity of *Cajanus cajan* and *Tamarindus indica* in alloxan-induced diabetic mice with a reference to in vitro antioxidant activity. *Pharm Res.* (2014) 44:580–3. doi: 10.4103/0253-7613.100380
136. Jarald E, Joshi S, Jain D, Edwin S. Biochemical evaluation of the hypoglycemic effects of extract and fraction of *Cassia fistula* Linn. in alloxan-induced diabetic rats. *Indian J Pharm Sci.* (2013) 75:427–34. doi: 10.4103/0250-474X.119823
137. Srividya AR, Dhanabal P, Bavadia P, Vishnuvarthan VJ, Kumar MNS. Antioxidant and antidiabetic activity of *Curcuma aromatica*. *Int J Ayurveda Pharm Res.* (2012) 3:401–5.
138. Mohammed A, Wudil AM, Alhassan AJ, Imam AA, Muhammad IU, Idi A. Hypoglycemic activity of *Curcuma longa* Linn root extracts on alloxan induced diabetic rats. *Saudi J Life Sci.* (2017) 2:43–9. doi: 10.21276/haya.2017.2.2.4
139. Raji RO, Muhammad HL, Abubakar A, Maikai SS, Raji HF. Acute and sub-acute toxicity profile of crude extract and fractions of *Gymnema sylvestre*. *Clin Phytoscience.* (2021) 7:56. doi: 10.1186/s40816-021-00290-4
140. Chen HW, Yang MY, Hung TW, Chang YC, Wang CJ. *Nelumbo nucifera* leaves extract attenuate the pathological progression of diabetic nephropathy in high-fat diet-fed and streptozotocin-induced diabetic rats. *J Food Drug.* (2019) 27:736–48. doi: 10.1016/j.jfda.2018.12.009
141. Chaudhary S, Semwal A, Kumar H, Verma HC, Kumar A. In-vivo study for anti-hyperglycemic potential of aqueous extract of basil seeds (*Ocimum basilicum* Linn) and its influence on biochemical parameters, serum electrolytes, and haematological indices. *Biomed Pharmacother.* (2016) 84:2008–13. doi: 10.1016/j.biopha.2016.11.020
142. Ardalani H, Hejazi Amiri F, Hadipanah A, Kongstad KT. Potential antidiabetic phytochemicals in plant roots: a review of in vivo studies. *J Diabetes Metab Disord.* (2021) 20:1837–54. doi: 10.1007/s40200-021-00853-9
143. Hannan J, Ojo O, Rokeya L, Khaleque J, Akhter M, Flatt P, et al. Actions underlying antidiabetic effects of *Ocimum sanctum* leaf extracts in animal models of type 1 and type 2 diabetes. *Eur J Med Chem.* (2014) 5:1–12. doi: 10.9734/EJMP/2015/11840
144. Almeleebia TM, Alsayari A, Wahab S. Pharmacological and clinical efficacy of *Picrorhiza kurroa* and its secondary metabolites: a comprehensive review. *Mol.* (2022) 27:8316. doi: 10.3390/molecules27238316
145. Paul S, Mandal SK, Bhattacharyya SS, Boujedaini N, Khuda-Bukhs AR. In vitro and in vivo studies demonstrate anticancer property of root extract of *Polygala senega*. *J Acupunct Meridian Stud.* (2010) 3:188–96. doi: 10.1016/S2005-2901(10)60035-0
146. Maiti A, Dewanjee S, Kundu M, Mandal SC. Evaluation of antidiabetic activity of the seeds of *Swietenia macrophylla* in diabetic rats. *Pharm Biol.* (2009) 47:132–6. doi: 10.1080/13880200802436703
147. Maiti R, Das UK, Ghosh D. Attenuation of hyperglycemia and hyperlipidemia in streptozotocin-induced diabetic rats by aqueous extract of seed of *Tamarindus indica*. *Biol Pharm Bull.* (2005) 28:1172–6. doi: 10.1248/bpb.28.1172
148. Farswan M, Mazumder PM, Parcha V. Modulatory effect of an isolated compound from *Syzygium cumini* seeds on biochemical parameters of diabetes in rats. *Int J Green Pharm.* (2009) 3:1–3. doi: 10.22377/ijgp.v3i2.428
149. Khera N, Bhargava S. Phytochemical and pharmacological evaluation of *Tectonia grandis* Linn. *Int J Pharm Sci.* (2013) 5:923–7.
150. Nadig PD, Revankar RR, Deth SM, Narayanswamy SB, Aliyar MA. Effect of *Tinospora cordifolia* on experimental diabetic neuropathy. *Indian J Pharmacol.* (2012) 44:580–3. doi: 10.4103/0253-7613.100380
151. Rajalakshmi M, Eliza J, Priya CE, Nirmala A, Daisy P. Anti-diabetic properties of *Tinospora cordifolia* stem extracts on streptozotocin-induced diabetic rats. *Afr J Pharmacol.* (2009) 3:171–80.
152. Ram H, Singh AK. Improvements in insulin resistance and β -cells dysfunction by DDP-4 inhibition potential of *Withania somnifera* (L.) dunal root extract in type 2 diabetic rat. *Biointerface Res Appl Chem.* (2020) 11:8141–55. doi: 10.33263/briac111.81418155
153. Udayakumar R, Kasthuriengan S, Mariashibu TS, Rajesh M, Anbazhagan VR, Kim SC, et al. Hypoglycaemic and hypolipidaemic effects of *Withania somnifera* root and leaf extracts on alloxan-induced diabetic rats. *Int J Mol Sci.* (2009) 10:2367–82. doi: 10.3390/ijms10052367
154. Nassiri M, Khaki A, Ahmadi-Ashtiani HR, Rezazadeh SH, Rastgar H, Gharachurlu S. Effects of ginger on spermatogenesis in streptozotocin-induced diabetic rat. *J Med Plants Stud.* (2009) 8:118–24.