Ethnopharmacological review of medicinal plants used to manage diabetes in Morocco

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Abstract

Diabetes is a chronic metabolic disorder which affects millions of people every year. If diabetes is not controlled, it can cause serious damage and a number of health complications. The aim of this paper was to review published ethnobotanical and ethnopharmacological evidences of Moroccan plants with antidiabetic potentials. Publications describing the medicinal plants used for the treatment of diabetes in Morocco were searched from the databases, including Google Scholar, Elsevier, Medline, Web of Science, SCOPUS and Pubmed. Other literature source was also used including books and theses available in library. About 750 literature references were studied, and only 240 research publications based on data from different Moroccan provinces published until June 2019 were included in this review. In total, 255 plants species belonging to 70 families were reported. Compositae and Lamiaceae were mentioned as the most represented families. The frequently used plant species in the dwellers of most regions of Morocco are Trigonella foenum-graecum, Artemesia herba-alba, Nigella sativa, Olea europaea, Allium cepa and Marrubium vulgare. This review provides useful information and current scientific knowledge on the medicinal plants used to manage diabetes in Morocco. Medicinal plants reported should be submitted to chemical, pharmacological and clinical studies to identify pharmacologically active metabolites and to confirm their antidiabetic activity.

Keywords: Medicinal plants, Diabetes, Ethnobotany, Pharmacology, Toxicology, Morocco

Introduction

Type 2 diabetes mellitus (T2DM), generally termed as diabetes, is one of the major endocrine diseases which affects millions of people in the industrial and developing countries [1, 2]. It is projected that the total number of people with diabetes worldwide is expected to increase to 592 million by 2035 [3]. Diabetes is a metabolic disease characterized by insufficient insulin secretion, impaired cellular action of the insulin or both [2, 4]. The characteristic symptoms of diabetes are pruritus, polydipsia, weight loss, polyphagia, wasting, blurred vision, polyuria, tachycardia and hypotension [5, 6]. Dietary and lifestyle factors (Obesity, weight gain, physical inactivity and low fiber diet with a high glycemic index) play a significant role in the development of diabetes [7]. Prolonged uncontrolled hyperglycemic level causes an increase in oxidative stress activation of the polyol pathway, coronary artery disease, peripheral arterial disease, stroke, diabetic nephropathy, neuropathy, peripheral neuropathy, retinopathy, retinopathy leading to vision loss, chronic kidney disease, urinary problems, sexual dysfunction, and skin infections [3, 8, 9]. The treatment of diabetes mellitus is based on insulin, diet modification and oral hypoglycemic agents. Herbal medicine has developed as an alternative for the treatment of diabetes because oral hypoglycemic agents are expensive and tagged with several side effects (nausea, skin reactions, liver disease, heart failure diarrhea, etc.) [10, 11]. In Morocco, there are numerous medicinal plants described for treatment of diabetes [2, 12–23].

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The aim of this review article was to collect data for species well-known for their antidiabetic effect in Morocco.

**Method**

Three researchers searched Google Scholar, Elsevier, Medline, Web of Science, SCOPUS and Pubmed bibliographic databases from January 2019 to July 2019 to extract all data about the use of plants in folklore medicine for treatment and management of diabetes in Morocco published in the period from January 1980 to June 2019, using English, French and Arabic keywords. The search terms used were “Ethnobotanical survey”, “Moroccan medicinal plants”, “anti-diabetic medicinal plants in Morocco”, “hypoglycemic plants in Morocco”, “diabetes in Morocco”. We reviewed the literature and collected data on the explored regions of Morocco (Beni Mellal region, Rabat, Western Anti-Atlas, Izaren forest, Oriental Morocco, Northwestern Morocco, Sefrou region, Central Middle Atlas, Tizi n’ Test Region, Al Haouz-Rhamna, Tan-Tan, Meknes-Tafilalet and Fez-Boulemane). About 750 literature references were studied, and only 240 ethnobotanical articles and pharmacology papers were included in this review. We did not include articles related to taxonomy, morphological characters, pharmacology, toxicity, ethnobotany, phytochemistry, clinical studies, cultivation, physiological, and anatomical aspects of all the medicinal plants mentioned. We studied in detail only the six plants most used for the treatment of diabetes in Morocco. We also excluded the articles without accessible full text and duplicate articles. Plant taxonomy is confirmed through data available on site (www.theplantlist.org).

**Results**

**Ethnobotanical studies**

A total of 255 plant species belonging to 70 families were reported as being used in the treatment and management of diabetes in Morocco (Table 1). Among plant families, Compositae had the highest number of species followed by Lamiaceae, Leguminosae, Apiaceae, Poaceae and Brassicaceae. Compositae was the most frequently cited plant family, which is consistent with the predominance of this plant family in the results of various studies conducted in other countries [3, 27, 28]. Compositae has been designated as the largest plant family of flowering plants worldwide, comprising 23,000 species and 1535 genera, including many with considerable medicinal importance [29, 30]. The traditional medicinal applications of several Compositae species have been recorded in the literature. Several bioactive compounds have been evaluated for their biological activities [31]. A wide use of Compositae family plants in Morocco could be due to the large number of plant species belonging to this family. Further, plants belonging to the Compositae family contain a group of active phytochemical constituents and some bitter-tasting secondary metabolites such as sesquiterpene lactones [8, 30].

Our evaluation of literature showed that indigenous people used 19 plant parts (leaf, aerial part, fruit, leafy stem, seed, root, bark, calyce, flower, stem, clove, gum, inflorescence, bark, pericarp, rhizome, stigma, tuber and young sprout) as herbal therapies for curing diabetes, but with, however, some preference for the leaves. Several procedures modes are used by the population to create medicinal formulations ( decoction, cooked, infusion, powder, maceration, juice, raw and cataplasm). However, extractions by decoction, powder or infusion remain the most common processes. Most medicinal formulations were used internally via oral route. The dose used varied considerably according to the patients questioned. The patients did not respect the precision of doses (some diabetics use specific doses, and others use non-specific doses). Often, people use a mixture of plants to treat diabetes. The duration of the use of plants was badly defined ranging from a few days to several years. The majority of people with diabetes have recourse in medicinal plants to treat diabetes. The percentage of use of phytotherapy varies between 51% and 90%, depending on the regions. The use of herbal medicine among certain diabetics was done in combination with their conventional treatment. Women frequently used more medicinal plants than men. Diabetics have discovered the disease by suggestive symptoms or by a screening test.

An ethnobotanical study was conducted out among 400 herbalists from the Beni Mellal region in order to identify the medicinal plants used for the traditional treatment by the diabetic patients. The results identified 45 species belonging to 25 botanical families. The most used species are: *Olea europaea*, *Salvia officinalis*, *Allium sativum* and *Trigonella foenum-graecum*. Leaves and roots are the most used parts [24].

To collect some information about antidiabetic plants used in Rabat (capital city of Morocco), a survey was undertaken from March 1st to April 30th 2018. The investigations revealed 30 species of plants belonging to 18 families. Lamiaceae and Leguminosae were the most commonly reported plant families. Interview results showed that the most frequently used plants were *Trigonella foenum-graecum*, *Salvia officinalis* and *Olea europaea* [25].

A survey was conducted by Barkaoui et al. [2], in Tizin (Western Anti-Atlas), in central Morocco. This study showed the importance of the use of medicinal plants by local population in the treatment of diabetes. Results have identified 48 medicinal plant species, belonging to 25 families and 44 genera, used for treating diabetes in the region. Plants growing in wild are most commonly
| Family          | Plant species                          | Vernacular name       | Part used       | Preparation                             | Number of citations | References |
|-----------------|----------------------------------------|-----------------------|-----------------|-----------------------------------------|---------------------|------------|
| Aizoaceae       | *Mesembryanthemum theurkauffii* (Maire) Maire | Afzu                  | Leaf and fruit  | Decoction and powder                    | 1                   | [18]       |
| Amaranthaceae   | *Arabidopsis arenosa* Moq. & Cos. ex Bunge | Chajra ma yehamekha rh/ selli | Aerial parts    | Decoction                               | 3                   | [17, 18, 21] |
| Amaranthaceae   | *Atriplex halimus* L.                   | Legtef                | Leaf            | Powder, decoction and maceration        | 1                   | [18]       |
| Amaranthaceae   | *Dyphyania ambrosioides* (L.) Mosyakin & Clemants | Mikhinza             | Leaf            | Infusion                                | 9                   | [12-14, 16, 18, 19, 22-24] |
| Amaranthaceae   | *Harrania scoparia* (Pomel) Iljin       | Assay                 | Seed            | Decoction                               | 1                   | [2]        |
| Amaranthaceae   | *Salsola tetragona* Delle               | Laarad                | Leaf and fruit  | Powder                                  | 1                   | [18]       |
| Amaryllidaceae  | *Allium ampeloprasum* L.                | Borro                 | Bulb            | Raw                                     | 2                   | [18, 25]   |
| Amaryllidaceae  | *Allium ceba* L.                        | Basla                 | Bulb            | Raw and juice                           | 14                  | [2, 12-22, 24, 25] |
| Amaryllidaceae  | *Allium sativum* L.                     | Tiskert / Tourma      | Bulb            | Raw                                     | 9                   | [12, 13, 17-19, 21-24] |
| Anacardiaceae   | *Pistacia atlantica* Desf.              | Btem/ agg/ Droui      | Fruit           | Decoction                               | 1                   | [2]        |
| Anacardiaceae   | *Pistacia lentiscus* L.                 | Trou / Tidekt         | Leaf, gum and ecorce | Infusion and decoction                  | 3                   | [13, 14, 17] |
| Anacardiaceae   | *Searsia albida* (Schoulb.) Moffett     | Zewaya/ anaffis       | Fruit           | Raw                                     | 1                   | [18]       |
| Anacardiaceae   | *Searsia tripartita* (Ucricia) Moffett  | Jdari                 | Leaf            | Powder                                  | 1                   | [18]       |
| Apiaceae        | *Ammi visnaga* (L.) Lam.                | Bachnikha / Barghanisse | Inflorescence (umbel) | Decoction                               | 11                  | [12-17, 19-23] |
| Apiaceae        | *Ammodaucus leucochris* Coss.           | Kamoun soufi          | Seed            | Infusion and decoction                  | 3                   | [12, 17, 18] |
| Apiaceae        | *Apium graveolens* L.                   | Krafess               | Seed            | Infusion                                | 1                   | [12]       |
| Apiaceae        | *Carum carvi* L.                        | Lkarwya               | Seed            | Decoction                               | 7                   | [2, 17-21, 24] |
| Apiaceae        | *Coriandrum sativum* L.                 | Kosbor                | Seed            | Infusion                                | 6                   | [12, 15-17, 20, 25] |
| Apiaceae        | *Cumminum cyminum* L.                   | Kamoun                | Seed            | Powder                                  | 2                   | [17, 18]   |
| Apiaceae        | *Daucus carata* L.                      | Khiouz                | Root            | Juice and puree                         | 3                   | [13, 17, 18] |
| Apiaceae        | *Eryngium ilicifolium* Lam.             | Tanannt / Igliffin    | Stem and leaf   | Decoction and powder                    | 1                   | [2]        |
| Apiaceae        | *Foeniculum vulgare* Mill.              | Naøxa                 | Seed            | Decoction                               | 9                   | [2, 12, 17-22, 24] |
| Apiaceae        | *Fastinga sativa* L.                    | Left imahfour         | Root            | Raw                                     | 2                   | [2, 24]    |
| Apiaceae        | *Petroselinum crispum* (Mill.) Fuss     | Maaxrouss            | Seed            | Infusion                                | 4                   | [12, 17, 18, 24] |
| Apiaceae        | *Pimpinella anisum* L.                  | Harbat ilawa          | Seed            | Decoction and powder                    | 7                   | [2, 12, 15, 17, 18, 24, 25] |
| Apiaceae        | *Ptychotis verticillata* Daby            | Nounikha              | Aerial parts    | Infusion                                | 2                   | [13, 23]   |
| Apiaceae        | *Riddia segetum* (L) Moris              | Tebch                 | Seed            | Powder                                  | 1                   | [17]       |
| Apocynaceae     | *Apteranthus europaea* (Guss.) Murb.    | Oukan iddan          | Stem            | Decoction, infusion, and raw            | 1                   | [2]        |
| Apocynaceae     | *Calotropis procera* (Alton) Dryand.    | Turja                 | Leaf            | Powder                                  | 1                   | [18]       |
| Apocynaceae     | *Caralluma europaea* (Guss.) NE Br.     | Daghmous              | Aerial parts    | Maceration                              | 3                   | [12, 17, 26] |
Table 1: Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies (Continued)

| Family          | Plant species               | Vernacular name     | Part used  | Preparation               | Number of citations | References |
|-----------------|----------------------------|---------------------|------------|---------------------------|---------------------|------------|
| Apocynaceae     | Nerium oleander L.         | Defla / Alili       | Leaf       | Fumigation and decoction  | 13                  | [2, 12, 14, 15, 17–24, 26] |
| Apocynaceae     | Periploca laevigata subsp. angustifolia (Labill.) Markgr. | Asllif               | Fruit      | Decoction                | 2                   | [2, 26]    |
| Arecaceae       | Chamaerops humilis L.      | Dum / Tigueden / Ignadd | Root       | Raw and cooked           | 2                   | [13, 17]   |
| Arecaceae       | Hyphaene thebaica (L.) Mart. | Dum / Xarur         | Fruit      | Powder                   | 1                   | [18]       |
| Arecaceae       | Phoenix dactylifera L.     | Tmar                 | Fruit      | Raw and decoction        | 5                   | [12, 17, 18, 20, 23] |
| Aristolochiaceae| Aristolochia baetica L.    | Tiswil nigrane / Benten | Root       | Powder                   | 1                   | [26]       |
| Aristolochiaceae| Aristolochia fontanesii Boiss. & Reut. | Berztem            | Seed       | Decoction                | 4                   | [15, 17–19]|
| Asparagaceae    | Agave americana L.         | Ssabra / Sayber     | Leaf       | Decoction                | 1                   | [17]       |
| Asparagaceae    | Asparagus albus L.         | Sekkum / Azzu       | Young sprouts | Raw                      | 1                   | [18]       |
| Berberidaceae   | Berberis vulgaris subsp. australis (Boiss.) Heywood | Anghris / Atizar | Leafy stem | Decoction                | 1                   | [17]       |
| Brassicaceae    | Anastatica hierochuntica L. | Chajarat Maryem / Ikemcha | Stem and leaf | Powder                   | 2                   | [13, 18]   |
| Brassicaceae    | Brassica napus L.          | Left                 | Rhizome    | Juice                    | 1                   | [18]       |
| Brassicaceae    | Brassica nigra (L.) Koch.  | Elkhadebi           | Flower     | Powder and infusion      | 1                   | [17]       |
| Brassicaceae    | Brassica oleracea L.       | Krumb mkawan/melluf | Aerial parts and fruit | Raw and maceration   | 4                   | [12, 13, 17, 18] |
| Brassicaceae    | Brassica rapa L.           | Left beldi           | Root and leaf | Decoction                | 2                   | [13, 17]   |
| Brassicaceae    | Diplotaxis pteridana Maire | Kerkaz / Elharra    | Flower     | Powder                   | 2                   | [17, 18]   |
| Brassicaceae    | Eruca vesicaria (L.) Cox.  | Ljerjir              | Aerial parts | Juice                   | 1                   | [18]       |
| Brassicaceae    | Lepidium sativum L.        | Hb enzechad         | Seed       | Maceration, decoction and infusion | 7                  | [12, 17–19, 21, 24, 25] |
| Brassicaceae    | Nasurtium officinale R.Br. | Gernunes             | Leafy stem | Maceration                | 1                   | [18]       |
| Brassicaceae    | Ptilotrichum spinosum (L.) Boiss. | Aguierbaz     | Stem and leaf | Decoction                | 1                   | [13]       |
| Brassicaceae    | Raphanus sativus L.        | Lifel                | Root       | Raw                      | 5                   | [2, 12, 17, 18, 24] |
| Buxaceae        | Buxa balearica Lam.        | Azaezet / Bakoous   | Leaf       | Decoction                | 2                   | [13, 17]   |
| Buxaceae        | Buxa sempervirens L.       | Lbeks                | Leaf       | Decoction                | 1                   | [19]       |
| Cactaceae       | Opuntia ficus indica (L.) Mill. | Lhndia / Aknari    | Stem, root and flower | Decoction, juice and powder | 10                  | [2, 12, 13, 15–18, 20, 22, 24] |
| Capparaceae     | Capparis decidua (Forssk.) Edgew. | Ignin              | Fruit      | Powder                   | 1                   | [18]       |
| Capparaceae     | Capparis spinosa L.        | Kabar / Taululut    | Aerial parts, fruit and root | Powder, decoction and infusion | 11                   | [13, 14, 16–23, 26] |
| Capparaceae     | Maerua cassifolia Forsk.   | Atili / Sedra Ikhdara | Leaf      | Powder and decoction     | 1                   | [18]       |
| Caryophyllaceae | Herniaria globra L.        | Hrasset lefiyer     | Aerial parts | Decoction                | 1                   | [22]       |
| Caryophyllaceae | Patonchya argentea Lam.    | Tahidout n'mksaoum  | Leafy stem | Infusion                 | 1                   | [26]       |
| Caryophyllaceae | Silene vivanii Steud.      | Gern lebzal         | Steem      | Raw                      | 1                   | [18]       |
| Family   | Plant species                          | Vernacular name | Part used                | Preparation | Number of citations | References |
|----------|----------------------------------------|----------------|--------------------------|-------------|---------------------|------------|
| Cistaceae| Cistus albidus L. Boutour              | Leaf           | Decoction                | 1           | [13]                |            |
| Cistaceae| Cistus creticus L. Irgel              | Leaf and powder| Infusion                 | 3           | [2, 17, 26]         |            |
| Cistaceae| Cistus laurifolius L. Aguilid         | Seed and flower| Powder                   | 2           | [17, 26]            |            |
| Cistaceae| Cistus salviifolius L. Irgel/Tirgelt | Leaf and seed  | Decoction and powder     | 2           | [2, 17]             |            |
| Colchicaceae | Androcymbium gramineum (Gav.) J.F.Macbr. | Temsrate leghrab | Infusion                | 1           | [17]                |            |
| Compositae | Achillea odorata L. Elqorte          | Leaf and flower| Infusion                 | 1           | [17]                |            |
| Compositae | Anacyclus pyrethrum (L.) Lag. Iguntas/Tagundeicht | Root | Infusion and powder | 1           | [13]                |            |
| Compositae | Antennaria dioica (L.) Gaertn. Ouden elfar | Leaf | Decoction                | 1           | [17]                |            |
| Compositae | Anvillea garcinii subsp. radiata (Coss. & Duarte) Anderb. | Negd | Decoction and powder     | 1           | [18]                |            |
| Compositae | Artemisia abrotanum L. Chih            | Aerial parts   | Decoction                | 1           | [17]                |            |
| Compositae | Artemisia absinthium L. Chiba         | Aerial parts   | Infusion                 | 10          | [12, 14, 16, 17, 19–26] |  |
| Compositae | Artemisia atlantica Coss. & Durieu Chih ourika | Aerial parts | Infusion                 | 1           | [17]                |            |
| Compositae | Artemisia heba-alba Asso Izri/Chih dwidi | Steam, leaf and root | Decoction and infusion | 15          | [2, 12, 14–26]      |            |
| Compositae | Artemisia mesatlantica Maire Chih alaflsatt/Chih elkhayssi | Aerial parts | Decoction                | 1           | [17]                |            |
| Compositae | Artemisia reptans C.Sm. ex Link Chihya | Leaf | Decoction                | 1           | [18]                |            |
| Compositae | Centaurea maroccana Bal Bejjaae nhal/Nogguir | Flower | Infusion                 | 1           | [17]                |            |
| Compositae | Chamaemelum nobile (L.) All. Babounj | Leaf | Decoction                | 2           | [15, 17]            |            |
| Compositae | Cichorium intybus L. Buuggad | Root | Infusion                 | 1           | [18]                |            |
| Compositae | Cladanthus arabicus (L.) Cass. Taafs | Flower | Infusion                 | 1           | [17]                |            |
| Compositae | Cladanthus scoriosus (Ball) Oberpr. & Vogt Arzgi| Flower | Decoction                | 1           | [26]                |            |
| Compositae | Cynara cardunculus L. Kharchouf | Aerial parts | Decoction                | 7           | [12, 15, 17–20, 22] |            |
| Compositae | Dittrichia viscosa (L.) Greuter Terehla/Bagraman | Leaf | Decoction                | 3           | [13, 17, 26]        |            |
| Compositae | Echinops spinosissimus Tuura Tarkra | Flower | Decoction                | 3           | [2, 15, 26]         |            |
| Compositae | Inula canya (Griess) DC. Terehla | Root | Decoction                | 1           | [17]                |            |
| Compositae | Inula helenium L. Terehla damatiya | Leaf and flower | Decoction and infusion | 1           | [17]                |            |
| Compositae | Launaea arborescens (Batt.) Murb. Iferskel/Moulbna | Stem, leaf, root and flower | Powder, decoction and infusion | 3           | [2, 17, 18]        |            |
| Compositae | Matricaria chamomilla L. Mansania | Leaf and flower | Decoction and infusion | 3           | [14, 17, 24]        |            |
| Compositae | Pallenis spinosa (L.) Cass. Nugd | Aerial parts | Decoction                | 1           | [17]                |            |
| Compositae | Scolymus hispanicus L. Gurnina/Taghdiut | Stem and leaf | Raw and decoction        | 3           | [13, 17, 26]        |            |
| Compositae | Scorzonera undulata Vahl Tamtla | Flower | Raw | 1           | [2]                |            |
| Family       | Plant species                  | Vernacular name | Part used | Preparation          | Number of citations | References |
|-------------|-------------------------------|----------------|----------|----------------------|---------------------|------------|
| Compositae  | *Sonchus arvensis* L.         | Kettan elhench  | Leaf     | Infusion             | 1                   | [15]       |
| Compositae  | *Sonchus tenerifanus* L.      | Tifaf           | Leaf     | Decocion             | 1                   | [18]       |
| Compositae  | *Tanacetum vulgare* L.        | Lbalsam         | Stem     | Infusion             | 1                   | [17]       |
| Compositae  | *Taraxacum campylodes* G.E.Haglund | Lhandba         | Flower and root | Decocion | 1                   | [17]       |
| Compositae  | *Watsonia saharae* Bentham ex Benth. & Coss. | Afssas         | Leaf     | Infusion and powder  | 2                   | [2, 18]    |
| Cucurbitaceae | *Citrullus colocynthis* (L.) Schrad. | Aferziz/lhdej  | Seed and fruit | Decocion, cataplasm and powder | 11                  | [2, 12, 13, 17–19, 21–23, 25, 26] |
| Cucurbitaceae | *Cucumis sativas* L.        | Likhias         | Fruit    | Raw                  | 6                   | [2, 12, 13, 17, 18, 24] |
| Cucurbitaceae | *Cucurbita maxima* Duchesne  | Garra Ihamia    | Leaf     | Decocion             | 1                   | [18]       |
| Cucurbitaceae | *Cucurbita pepo* L.          | Takhsait/curjt  | Fruit    | Decocion and decoction | 5                   | [13, 14, 17, 18, 24] |
| Cypresaeae   | *Juniperus phoenicea* L.      | Araar finiqui   | Leaf and aerial parts | Powder, decoction and maceration | 4                   | [13, 17–19] |
| Cypresaeae   | *Juniperus thurifera* L.      | Tawayt          | Leaf     | Decocion             | 1                   | [13]       |
| Cypresaeae   | *Tetraclin. articulata* (Vahl. Mast.) | Araar         | Leaf and aerial parts | Infusion and maceration | 9                   | [12–15, 17, 21–24] |
| Cyno-moraceae | *Cynomortum coccinum* L.     | Tertut          | Steem    | Powder               | 1                   | [18]       |
| Cyperaceae   | *Bolboschoenus maritimus* (L.) Pallia | Samar         | Seed     | Decocion             | 1                   | [17]       |
| Cyperaceae   | *Cyperus rotundus* L.         | Tara            | Leaf     | Powder               | 1                   | [18]       |
| Dracaenaceae | *Dracaena draco* subsp. aigal Benabid & Cuzin | Aigal       | Stem and leaf | Decocion             | 1                   | [2]        |
| Ephedraceae  | *Ephedra alata* Decne.       | Chhida          | Leafy stem | Decocion and powder | 1                   | [18]       |
| Ephedraceae  | *Ephedra atissima* Desf.     | Tougel argan    | Leafy stem and wholeplant | Decocion             | 2                   | [2, 24]    |
| Ephedraceae  | *Ephedra fragilis* Desf.     | Amater          | Leafy stem | Decocion             | 1                   | [26]       |
| Ericaceae   | *Arbutus unedo* L.           | Sainsu          | Leaf and root | Decocion | 5                   | [13, 14, 22–24] |
| Euphorbiaceae | *Euphorbia officinarum* subsp. echinus (Hook. f. & Coss.) Vindt | Tikiout/Daghmous/zakour | Fruit, stem and leaf | Maceration, decoction, powder and juice | 4                   | [2, 16–18] |
| Euphorbiaceae | *Euphorbia officinarum* L.   | Tikiout/Daghmous | Stem and leaf | Powder             | 1                   | [2]        |
| Euphorbiaceae | *Euphorbia resinifera* O.Berg | Tikiwt         | Leaf     | A drop latex in a glass of water | 4                   | [13, 19, 24, 26] |
| Euphorbiaceae | *Mercurialis annua* L.       | Humiga elmaissa | Leafy stem | Infusion, decoction and juice | 2                   | [17, 18]  |
| Euphorbiaceae | *Ricinus communis* L.        | Awniweer/Lhkarwaa | Seed     | Poultice             | 1                   | [18]       |
| Fagaceae     | *Quercus cocifera* L.        | Elgermez        | Leaf     | Decocion             | 1                   | [17]       |
| Gentianaceae | *Centaurium erythraea* Rafn   | Qusset elhayya / Ahchaf ntawra | Flowering and aerial parts | Infusion and decoction | 4                   | [13, 14, 17, 22] |
| Iridaceae    | *Crocus sativus* L.          | Zaafren lhor    | Stigma   | Infusion             | 1                   | [18]       |
| Juglandaceae | *Juglans regia* L.           | Swak / Gargaa   | Leaf and bark | Infusion and decoction | 6                   | [13, 17, 18, 22, 23, 26] |
| Juncaceae    | *Juncus maritimus* Lam.      | Ssemar          | Fruit and stem | Decocion             | 2                   | [17, 18]  |
Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies (Continued)

| Family       | Plant species               | Vernacular name                 | Part used         | Preparation                     | Number of citations | References |
|--------------|-----------------------------|---------------------------------|-------------------|---------------------------------|---------------------|------------|
| Lamiaceae    | Ajuga iva (L.) Schreb.      | Timerna nzenkhad/ Chndkoura      | Stem and leaf     | Powder and decoction            | 12                  | [2, 12–15, 17–19, 22–24, 26] |
| Lamiaceae    | Ballota hirsuta Benth.      | Merou elhrami/Merou             | Leafy stem        | Decoction                       | 1                   | [17]       |
| Lamiaceae    | Clinopodium alpinum (L.) Kuntze | Zitta                          | Leaf              | Decoction                       | 2                   | [18, 25]   |
| Lamiaceae    | Clinopodium nepeta subsp. glandulosum (Req.) Govaerts | Manta                      | Aerial parts      | Infusion and decoction          | 2                   | [14, 15]   |
| Lamiaceae    | Lavandula angustifolia Mill | Elkhzama zerra/ Elkhzama Fassiya | Aerial parts and leafy stem | Infusion and decoction          | 1                   | [17]       |
| Lamiaceae    | Lavandula dentata L.        | Timzenia/Lakhzama/ Jaada        | Stem and leaf     | Decoction, powder, infusion and raw | 6                   | [2, 14, 17, 21–23] |
| Lamiaceae    | Lavandula maroccana Murb.   | Igazien                         | Stem and leaf     | Decoction                       | 2                   | [2, 26]    |
| Lamiaceae    | Lavandula multifida L.      | Khilt Ilkhey/ Kohayla           | Leaf              | Decoction                       | 1                   | [18]       |
| Lamiaceae    | Lavandula stoechas L.       | Imzeria/Tikeni/Te/mina          | Leaf              | Decoction                       | 5                   | [2, 12, 13, 17, 18] |
| Lamiaceae    | Marrubium vulgare L.        | Mriwit/fizi                     | Leaf and aerial parts | Decoction and infusion      | 14                  | [2, 12–19, 21–25] |
| Lamiaceae    | Mentha pulegium L.          | Filou                           | Leaf and aerial parts | Decoction and infusion      | 8                   | [2, 13, 15, 17–19, 21, 23, 25] |
| Lamiaceae    | Mentha spicata L.           | Nanaa/Liqama                   | Leaf and leafy stem | Infusion and decoction          | 2                   | [17, 18]   |
| Lamiaceae    | Ocimum basilicum L.         | Lahbaq                          | Stem              | Infusion                        | 2                   | [13, 17]   |
| Lamiaceae    | Origanum compactum Benth.   | Azukenni/Zaaten/ Zaatar tadlawi | Stem and leaf     | Decoction and infusion          | 8                   | [13–15, 17, 18, 21–23] |
| Lamiaceae    | Origanum elongatum (Bonnet) Emb. & Maire | Zaater                        | Leaf              | Infusion                        | 1                   | [25]       |
| Lamiaceae    | Origanum majorana L.        | Berdedouch                      | Leaf              | Powder                          | 1                   | [13]       |
| Lamiaceae    | Origanum vulgare L.         | Zaatar                          | Leaf              | Infusion                        | 1                   | [12]       |
| Lamiaceae    | Rosmarinus officinalis L.   | Azir                            | Leaf              | Powder, decoction and infusion  | 11                  | [2, 13–15, 17–19, 21–23, 25] |
| Lamiaceae    | Salvia officinalis L.       | Salmia                          | Leaf              | Decoction and infusion          | 11                  | [2, 12, 13, 15–19, 22–24, 26] |
| Lamiaceae    | Teucrium pollium L.         | Tawerent/Flooe Ilbou/jaidia     | Leaf              | Decoction and powder            | 3                   | [2, 19, 26] |
| Lamiaceae    | Thymus braunsteini Boiss.   | Zietra                          | Leaf and stem     | Infusion and maceration         | 1                   | [23]       |
| Lamiaceae    | Thymus algeriensis Boiss. & Reut. | Aduchen /Azukin / Zutra     | Stem and leaf     | Decoction and infusion          | 1                   | [13]       |
| Lamiaceae    | Thymus munchyanus Boiss. & Reut. | Aduchen /Azukin / Zutra     | Stem and leaf     | Decoction and infusion          | 1                   | [13]       |
| Lamiaceae    | Thymus satuvudlesi Coss.    | Asserkna/ Zita                 | Leaf              | Infusion, decoction, powder, and maceration | 2 | [2, 17] |
| Lamiaceae    | Thymus vulgaris L.          | Aduchen /Azukin / Zutra         | Leaf              | Decoction and infusion          | 3                   | [2, 13, 17] |
| Lamiaceae    | Thymus zygis L.             | Aduchen /Azukin / Zutra         | Stem and leaf     | Decoction and infusion          | 1                   | [13]       |
| Lauraceae    | Cinnamomum cassia (L.) JPresl | Qarfa                         | Bark              | Decoction                       | 5                   | [13, 15, 17, 19, 21] |
| Lauraceae    | Cinnamomum verum JPresl     | Dar esimi                       | Bark              | Maceration                      | 3                   | [17, 18, 25] |
| Lauraceae    | Laurus nobilis L.           | Ourak sidna moussia/ Rand      | Leaf              | Infusion and decoction          | 2                   | [12, 17]   |
| Lauraceae    | Paeonia americana Mill.     | Lavoca                          | Seed              | Powder                          | 4                   | [16, 18, 19, 25] |
| Family            | Plant species                        | Vernacular name                      | Part used                                | Preparation                        | Number of citations | References |
|-------------------|--------------------------------------|---------------------------------------|------------------------------------------|------------------------------------|---------------------|------------|
| Leguminosae       | Acacia nilotica (L.) Delile           | Amur/Sllaha                           | Fruit                                    | Powder                            | 1                   | [18]       |
| Leguminosae       | Acacia senegal (L.) Willd.            | Laalek                                | Gum                                      | Powder                            | 1                   | [18]       |
| Leguminosae       | Acacia tortilis (Forsk.) Hayne        | Telt/Tadoute                          | Root, fruit and leaf                     | Decoction and powder              | 2                   | [17, 18]  |
| Leguminosae       | Anagyra foetida L.                    | Ful gnawa                             | Powder                                   | 1                                 | [18]                |
| Leguminosae       | Arachis hypogaea L.                   | Lgerta/Kawkaw                         | Powder                                   | 1                                 | [18]                |
| Leguminosae       | Ceratonia silqua L.                   | Tikida/Ukharoub                       | Leaf and seed                            | Decoction, infusion and powder    | 6                   | [2, 12, 17, 18, 24, 25] |
| Leguminosae       | Cicer arietinum L.                    | Lhemmes                               | Seed                                     | Decoction and powder              | 2                   | [18, 24]  |
| Leguminosae       | Faidherbia albida (Delile) A.Chev.    | Chok/Talh/Mimouza                     | Root                                     | 1                                 | [17]                |
| Leguminosae       | Glycine max (L.) Merr.                | Soja                                  | Seed                                     | Maceration and raw                | 5                   | [2, 12, 20, 24, 26] |
| Leguminosae       | Glycyrhiza glabra L.                  | Ark souss                             | Bark                                     | Infusion                          | 1                   | [25]       |
| Leguminosae       | Lupinus albus L.                      | Tims/Foul gnawa                       | Seed                                     | Powder and decoction              | 3                   | [2, 17, 26] |
| Leguminosae       | Lupinus angustifolius L.              | Ilbawn delkouk                        | Seed                                     | Powder and decoction              | 7                   | [16-19, 21, 24, 22, 24] |
| Leguminosae       | Lupinus luteus L.                     | Kite/Semqala                          | Seed                                     | Decoction                          | 1                   | [17]       |
| Leguminosae       | Medicago sativa L.                    | Fassa                                 | Aerial parts and seed                    | Infusion, maceration and cooked   | 5                   | [12, 13, 17, 18, 24] |
| Leguminosae       | Ononis natrix L.                      | Hennet reg                            | Leaf                                     | Decoction                          | 1                   | [18]       |
| Leguminosae       | Ononis tournefortii Cass.             | Afezadad                              | Leaf                                     | Decoction                          | 1                   | [18]       |
| Leguminosae       | Phaseolus vulgaris L.                 | Lubyia                                | Fruit                                    | Decoction, powder and Juice       | 4                   | [13, 16-18] |
| Leguminosae       | Retama ochraem (Forsk.) Webb          | Rtam/Allug                            | Root and leaf                            | Decoction                          | 1                   | [17]       |
| Leguminosae       | Retama sphaerocarpa (L.) Boiss.       | Rtem                                  | Root                                     | Decoction                          | 1                   | [20]       |
| Leguminosae       | Trigonella foenum-graecum L.          | Lhelba/Tifidas                        | Seed                                     | Decoction, infusion, maceration and powder | 16                  | [2, 12-26] |
| Leguminosae       | Vicia faba L.                         | Ful                                    | Seed                                     | Powder                            | 1                   | [18]       |
| Leguminosae       | Vicia sativa L.                       | Ayn larnab                            | Seed                                     | Powder                            | 1                   | [18]       |
| Leguminosae       | Vigna radiata (L.) R.Wilczek          | Soja                                  | Seed                                     | Powder                            | 1                   | [18]       |
| Leguminosae       | Vigna unguiculata (L) Walp            | Ful gnawa                             | Seed                                     | Decoction                          | 1                   | [17]       |
| Linaceae           | Linum usitatissimum L.                | Zariat elkattan                       | Seed                                     | Decoction and powder              | 7                   | [2, 13, 15, 17, 18, 21, 25] |
| Lythraceae         | Lawsonia hermis L.                    | Lhenna                                | Leaf                                     | Decoction and cataplasme           | 2                   | [17, 21]  |
| Lythraceae         | Punica granatum L.                    | Rman                                  | Pericarp                                 | Decoction, infusion, and powder   | 8                   | [2, 13, 15, 17-21] |
| Malvaceae          | Abelmoschus esculentus (L) Moench    | Lmloukhia                             | Fruit                                    | Maceration                         | 2                   | [13, 25]  |
| Malvaceae          | Hibiscus sabdarfla L.                 | Karkad/Bissam                         | Calyces                                  | Infusion                           | 3                   | [17, 18, 26] |
| Molluginaceae      | Corrigiola litoralis subsp. telephilia (Pourr.) Briq. | Sarghina / Tawsarghine | Root                                     | Powder                            | 2                   | [13, 17]  |
| Moraceae           | Ficus carica L.                       | Tazart/Karmous/Karma/chriha/Elbakur   | Fruit and leaf                           | Decoction                          | 8                   | [2, 13, 15, 17, 20, 22-24] |
| Family       | Plant species            | Vernacular name | Part used       | Preparation          | Number of citations | References          |
|--------------|--------------------------|-----------------|-----------------|----------------------|---------------------|---------------------|
| Moraceae     | Morus alba L.            | Tut lbari       | Leaf            | Infusion             | 3                   | [13, 17, 19]        |
| Musaceae     | Musa × paradisiaca L.    | Banan           | Leaf            | Decoction            | 1                   | [18]                |
| Myrtaceae    | Myristica fragrans Houtt. | Lgoua           | Seed            | Powder               | 1                   | [2]                 |
| Myrtaceae    | Eucalyptus camaldulensis Dehnh. | Calitūs        | Leaf            | Decoction            | 1                   | [18]                |
| Myrtaceae    | Eucalyptus globulus Labill. | Calitūs        | Leaf and fruit  | Decoction            | 8                   | [13–15, 17, 21–24]  |
| Myrtaceae    | Myrtus communis L.       | Rihane          | Leaf and fruit  | Decoction and infusion | 8 | [13, 14, 17, 20–24] |
| Myrtaceae    | Syzygium aromaticum (L.) Merr. & L.M.Perry | Kranfal        | Fruit and clove | Infusion, decoction, powder and maceration | 8 | [2, 14, 17–19, 22, 24, 25] |
| Nitriaceae   | Peganum harmala L.       | Lharmel         | Seed            | Infusion and powder  | 7                   | [13, 15, 17, 20–23] |
| Oleaceae     | Fraxinus angustifolia Vahl | Touzalt        | Leaf            | Infusion             | 2                   | [13, 23]            |
| Oleaceae     | Olea europaea L.         | Jbouj/Azmour/Zitoun | Leaf, fruit and flower | Decoction, infusion, maceration and powder | 15 | [2, 12, 13, 15–26] |
| Papaveracea  | Fumaria officinalis L.    | Hochichat assebyane | Root            | Decoction            | 1                   | [17]                |
| Papaveracea  | Papaver rhoeas L.        | Belaaman        | Seed            | Powder               | 3                   | [2, 24, 26]         |
| Pedaliaceae  | Sesamum indicum L.       | Janjān          | Seed            | Powder, infusion and decoction | 7 | [2, 14, 18, 20–22, 24] |
| Plantaginaceae | Globularia dyperm L.   | Ayen lernab/ Taselgha | Flower, leaf and stem | Infusion and decoction | 10 | [13, 15–19, 21–23, 26] |
| Plantaginaceae | Globularia repens Lam. | Ain lernab     | Leaf            | Decoction            | 1                   | [12]                |
| Plumbaginaceae | Limonium sinuatum (L.) Mill. | Lgara          | Leaf            | Decoction            | 1                   | [18]                |
| Poaceae      | Avena sativa L.          | Khortal         | Seed            | Powder, infusion and decoction | 2 | [13, 17]         |
| Poaceae      | Avena sterilis L.        | Waskone/ Khortal | Seed            | Powder               | 1                   | [26]                |
| Poaceae      | Castilla tuberculosa (Moris) Bor | Zvan Imkarkeb | Seed            | Decoction            | 1                   | [17]                |
| Poaceae      | Cynodon dactylon (L.) Pers. | Njem          | Root            | Decoction            | 1                   | [18]                |
| Poaceae      | Hordeum vulgare L.       | Chair/Zraa     | Aerial parts and seed | Infusion, powder and maceration | 3 | [2, 17, 18] |
| Poaceae      | Lolium perenne L.        | Ezizwane       | Seed            | Decoction            | 1                   | [26]                |
| Poaceae      | Panicum milaceum L.      | Taффσout       | Seed            | Decoction            | 1                   | [17]                |
| Poaceae      | Panicum turgidum Forssk. | Umm rekba     | Stem            | Decoction and powder | 1                   | [18]                |
| Poaceae      | Pennisetum glaucum (L.) R.Br. | Illan         | Seed            | Infusion and powder  | 3                   | [12, 17, 18]        |
| Poaceae      | Phalaris canariensis L.  | Zouan          | Seed and fruit  | Powder, infusion and decoction | 6 | [2, 13, 14, 15, 17, 24] |
| Poaceae      | Polygonon monspeliensis (L.) Desf. | Tugga       | Fruit          | Raw                  | 1                   | [18]                |
| Poaceae      | Sorghum bicolor (L.) Moench | Bachna       | Seed            | Infusion and decoction | 3 | [13, 15, 23] |
| Poaceae      | Triticum durum Desf.     | Zaa            | Seed            | Decoction            | 1                   | [17]                |
| Poaceae      | Zea mays L.              | Lahyat Adia   | Stigmas        | Powder               | 3                   | [14, 24, 26]        |
| Polygonaceae | Emex spinosa (L.) Campd. | Lhenzab        | Leaf and bulb   | Powder               | 1                   | [18]                |
| Portulacaceae | Portulaca deracea L.     | Rejla          | Aerial parts    | Decoction            | 3                   | [12, 17, 26]        |
Table 1: Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies (Continued)

| Family                | Plant species                  | Vernacular name                | Part used        | Preparation               | Number of citations | References               |
|-----------------------|--------------------------------|--------------------------------|------------------|---------------------------|---------------------|--------------------------|
| Ranunculaceae         | Nigella sativa L.              | Haba souda /Sanouj             | Seed             | Infusion, decoction and powder | 15                  | [2, 13–26]               |
| Rhamnaceae            | Ziziphus lotus (L.) Lam.        | Nbeg/Azouggaissdra             | Leaf, fruit and root | Decoction and powder       | 10                  | [2, 15, 17–20, 22–24, 26] |
| Rosaceae              | Cydonia oblonga Mill.          | Slfjerel                       | Fruit            | Raw                        | 1                   | [20]                     |
| Rosaceae              | Chaenomeles sinensis (Dum.Cour.) Koehne | Slfjerel                     | Root             | Decoction                  | 2                   | [18, 22]                 |
| Rosaceae              | Eriobotrya japonica (Thunb.) Lindl. | Mzah                  | Leaf             | Infusion                   | 3                   | [13, 15, 23]             |
| Rosaceae              | Fragaria vesca L.              | Fraiz bent                     | Fruit            | Juice                      | 1                   | [22]                     |
| Rosaceae              | Malus communis (L.) Poir.      | Etetah                         | Fruit            | Juice                      | 1                   | [26]                     |
| Rosaceae              | Prunus armenica L.             | Luz elhar                      | Seed             | Decoction                  | 1                   | [17]                     |
| Rosaceae              | Prunus dulcis (Mill.) D.A. Webb | Louz imdizg/ Louz morr         | Seed and leaf    | Raw and decoction          | 12                  | [2, 14, 15, 17, 18, 20–26] |
| Rosaceae              | Rubus vulgaris Weihe & Nees    | Laalig                         | Leaf             | Powder                     | 1                   | [17]                     |
| Rubiaceae             | Rubia tinctora L.              | Fowwa                          | Root             | Powder                     | 1                   | [18]                     |
| Rosaceae              | Citrus medica L.               | Lhamed belld                   | Fruit            | Juice and infusion         | 1                   | [17]                     |
| Rutaceae              | Citrus paradisi Macfad.        | Pambilamus                     | Fruit            | Juice                      | 1                   | [17]                     |
| Rutaceae              | Citrus sinensis (L.) Osbeck    | Limun                          | Fruit            | Juice, raw and juice       | 2                   | [12, 18]                 |
| Rutaceae              | Citrus × aurantium L.          | Larenj/Zenbue/trunj            | Leaf, fruit and flower | Juice, infusion and decoction | 7           | [14, 16–21]              |
| Rutaceae              | Ruta graveolens L.             | Lfijel                         | Root             | Decoction                  | 2                   | [17, 18]                 |
| Rutaceae              | Ruta montana (L.) L.           | Lfijel/Awermi                  | Stem and leaf    | Decoction, infusion and powder | 7           | [13–15, 17, 19, 20, 23]  |
| Salicaceae            | Solanum americanum Mill.       | Aneb dib                       | Leaf             | Decoction                  | 1                   | [17]                     |
| Salicaceae            | Salix alba L.                  | Salif lma                      | Leaf             | Infusion                   | 1                   | [15]                     |
| Santalaceae           | Viscum album L.                | Lenjbar                        | Seed             | Decoction, infusion and powder | 8           | [2, 13, 15–18, 25, 26]   |
| Sapotaceae            | Argania spinosa (L.) Skeels    | Argan                          | Seed             | Raw and powder             | 8                   | [2, 13, 15–18, 25, 26]   |
| Schisandraceae        | Illicium verum Hook.f.         | Badiara                        | Fruit            | Decoction                  | 1                   | [17]                     |
| Solanaceae            | Capsicum annuum L.             | Felfel Hârr/ soudania          | Fruit            | Raw                        | 3                   | [13, 14, 18]             |
| Solanaceae            | Datura stramonium L.           | Sdag jmel/Metall              | Seed             | Decoction                  | 1                   | [18]                     |
| Solanaceae            | Lycopersicon esculentum Mill.  | Matcha                         | Fruit            | Raw                        | 2                   | [17, 18]                 |
| Solanaceae            | Nicotiana tabacum L.           | Nefha                          | Leaf             | Decoction                  | 1                   | [14]                     |
| Solanaceae            | Solanum americanum Mill.       | Aneb dib                       | Leaf             | Infusion                   | 1                   | [17]                     |
| Taxaceae              | Taxus baccata L.               | Guelguem/Aguelguimt           | Root             | Decoction                  | 1                   | [17]                     |
| Thaceae               | Camellia sinensis (L.) Kuntze  | Attay                          | Leaf             | Infusion and decoction     | 6                   | [2, 12, 15, 17, 18, 24]  |
| Thymelaceae           | Thymelaea hirsuta (L.) Endl.    | Metnan                         | Leafy stem       | Powder                     | 2                   | [17, 23]                 |
| Thymelaceae           | Thymelaea tartonsaica (L.) All. | Talâazt                       | Leaf             | Decoction                  | 1                   | [20]                     |
| Thymelaceae           | Thymelaea veigata (Desf.) Endl.| Metnan                         | Leafy stem       | Decoction                  | 1                   | [17]                     |
| Urticaceae            | Urtica dioica L.               | Taznagt/Tigzenin/Lhriga       | Stem and leaf    | Decoction and infusion     | 8                   | [2, 14, 15, 17, 19, 23, 24, 26] |
| Urticaceae            | Urtica pilulifera L.           | Hurriga / Tirsalmaz           | Leaf             | Decoction                  | 2                   | [13, 22]                 |
Table 1 Plants used in the treatment of diabetes in Morocco, cited in ethnobotanical studies (Continued)

| Family          | Plant species                      | Vernacular name  | Part used | Preparation                  | Number of citations | References       |
|-----------------|-----------------------------------|------------------|-----------|------------------------------|---------------------|------------------|
| Verbenaceae     | Aloysia citriodora Palau           | Alwiza           | Leaf      | Decoction and infusion       | 4                   | [14–16, 18]      |
| Verbenaceae     | Verbena officinalis L.             | Alwiza           | Leaf      | Decoction                    | 1                   | [25]             |
| Vitaceae        | Vitis vinifera L.                  | Dalya/Zbib/Kerma/Adllite | Leaf | Decoction                    | 3                   | [17, 18, 20]     |
| Xanthorrhoeaceae| Aloe succotrina Lam.               | Ssabra/Siber     | Leaf      | Powder                       | 5                   | [15, 17, 18, 21, 22] |
| Xanthorrhoeaceae| Asphodelus microcarpus Salzm. & Viv.| Lberwag/blakuz/Tazia | Tuber | Raw                          | 2                   | [17, 18]         |
| Xanthorrhoeaceae| Asphodelus tenuifolius Cav.        | Lehyat al aatrus/Tazya/Lberiwiga | Leaf | Decoction                    | 1                   | [17]             |
| Zingiberaceae   | Zingiber officinal Roscoee         | Sekinjbir        | Rhizome   | Decoction, infusion, powder and maceration | 5                   | [14, 15, 18, 19, 25] |
| Zygophyllaceae  | Tetraena gætula (Emb. & Maire) Beier & Thulin | Aagaia          | Leaf, root and seed | Powder, Infusion and decoction | 10                  | [2, 13, 14, 17–23] |
used for medicinal purposes in the study area (32 plant species). According to the authors, *Allium sativum* L., *Salvia officinalis* L., *Marrubium vulgare* L. and *Lavandula dentata* L. were the most frequently used plants to treat diabetes. Six plants were reported for the first time as hypoglycemic plants: *Dracaena draco* subsp. *ajgal*, *Euphorbia officinarum* subsp. *officinarum*, *Eryngium illicifolium* Lam., *Pastinaca sativa* L., *Scorzonera undulata*, *Ephedra altissima* Desf.

In Izarene forest (Northern Morocco), a survey was undertaken in order to inventory the main medicinal plants used in folk medicine to treat diabetes and arterial hypertension. The results obtained allowed an inventory of 40 medicinal plant species used against diabetes. The most cited plants for the treatment of diabetes were: *Trigonella foenum-graecum*, *Artemisia herba-alba*, *Ammi visnaga*, *Centaurium erythraea*, *Myrtus communis*, *Globularia alypum*, *Nigella sativa*, *Tetraena gaetul*, *Olea europaea*, *Rosmarinus officinalis*, *Marrubium vulgare*, *Allium cepa*, *Ajuga iva*, *Salvia officinalis*, *Artemesia absinthium*, *Prunus dulcis*, *Capsicum annuum*, *Origanum compactum*, *Nerium oleander*, and *Urtica dioica* [14].

An ethnobotanical survey by Ziyyat et al. [23] in different areas of Oriental Morocco reported that 34 plant species were used for the treatment of diabetes, of which the most used were *Trigonella foenum-graecum*, *Globularia alypum*, *Artemisia herba-alba*, *Citrus colocythys* and *Tetraclinis articulata*. Also a study was carried out in Oriental Morocco with 279 diabetic patients at the Department of Endocrinology and Metabolism of Mohammed VI University Hospital in Oujda. The results showed that the local population uses medicinal plants for the treatment of diabetes. Fifty plants are reported to be used in the region for the treatment of diabetes. The five most common herbal medicines used were *Salvia officinalis*, *Trigonella foenum-graecum*, *Olea europaea*, *Artemisia herba-alba* and *Origanum vulgare* [15].

A study by Laadim et al. [12] in Sidi Slimane (northwestern Morocco) reported that 59 plant species were cited by 700 diabetic patients for management of diabetes. Five plants, *Trigonella foenum-graecum*, *Oreganum vulgare*, *Salvia officinalis*, *Marrubium vulgare* and *Olea europaea*, were most used. The survey revealed that seeds and leaves are the part of the plant most often used in herbal preparations.

In an ethnobotanical survey by Bousta et al. [16], 22 species of plants belonging to 19 families were reported for the treatment of diabetes in the Middle-Atlas region of Morocco (Sefrou region). The most prominent plants reported were *Olea europaea*, *Salvia officinalis*, *Trigonella foenum-graecum*, *Euphorbia officinarum* subsp. *echinus*, *Globularia alypum*, *Coriandrum sativum*. Respondents said that they inherited the knowledge of their practices from their parents, traditional healers, some books and nowadays from television programs.

Also in the Central Middle Atlas an ethnobotanical study identified 76 medicinal plants, divided into 67 genus and 40 families. Fourteen plants are reported for the first time intraditional treatment of diabetes in Morocco. They are: *Pistacia atlantica*, *Anacyclus pyrethrum*, *Ptilotrichum spinosum*, *Cistus albidus*, *Juniperus thurifera*, *Thymus algeriensis*, *Thymus mumbayanus*, *Thymus zygis*, *Abelmoschus esculentus*, *Frasinus angustifolia*, *Sorghum bicolor* and *Eriobotrya japonica* [13].

To inventory the medicinal plants used in traditional medicine to treat diabetes in the Tizi n’ Test Region (Tarfoudant Province), a survey was carried using semi-structured and structured questionnaires. Thirty-nine plant species belonging to 24 botanical families were recorded for the treatment of diabetes. The most important species were *Artemisia herba-alba*, *Cistus creticus*, *Lavandula maroccana*, *Salvia officinalis* and *Olea europaea*. Leaves were the parts predominantly used and decoction was the most common method to prepare the formulations [26].

Another ethnobotanical survey among the local population in the region of Al Haouz-Rhamna (central Morocco) reported that a total of 150 plant species belonging to 54 families were used for the treatment of diabetes in the area. Among these species recorded 18 are cited for the first time in the region as an antidabetic plants namely: *Chamaeops humilis*, *Cladanthus arabicus*, *Centauraea maroccana*, *Matricaria chamomilla*, *Tanacetum vulgare*, *Diplotaxis pitardiana*, *Berberis vulgaris* subsp. *australis*, *Corrigiola litoralis* subsp. *telephifolia*, *Cistus laurifolius*, *Quercus cocifera*, *Ballota hirsuta*, *Buxus baleareica*, *Lavandula stoechas*, *Ocimum basilicum*, *Thymus statureoides*, *Ruta montana*, *Taxus baccata* and *Thymelaea virgata* [17].

In the region of Tan-Tan (South of Morocco), a survey reported that 129 medicinal species belonging to 53 families were cited by 350 people for the treatment of diabetes with the dominance of the most represented families in the flora of Morocco. Some of the inventoried plant species are endemic to the Sahara such as *Cynomorium coccineum*, *Atriplex halimus* and *Salsola tetragona*, but others are toxic including *Aristolochia fontanesii*, *Euphorbia officinarum* and *Nerium oleander* [18].

In the region of Meknes-Taflalet (North-central Morocco), an ethnobotanical study was undertaken in order to inventory the main medicinal plants used in folk medicine to treat diabetes. In this region, the most frequently used plants include *Allium cepa*, *Artemisia herba-alba* and *Trigonella foenum graecum* [19]. Also in the North central region of Morocco (Fez–Boulemane), an ethnobotanical study reported that 90 medicinal species are used in the treatment of diabetes, hypertension
and renal diseases. Among these species, 9 plants are toxic at high doses. For diabetes, 54 plants were cited, of which the most cited were: Artemisia herba alba, Trigonella foenum-graecum and Tetraena gaetula [22].

In the Errachidia province (South-eastern Morocco), a survey was carried out to catalog the plants traditionally used in the treatment of hypertension and diabetes mellitus. The authors have inventoried 64 species belonging to 33 families, of which 45 plants were used in the treatment of diabetes. The most frequently cited plant species by the local population for management of diabetes are Ajuga iva, Allium cepa, Artemisia herba-alba, Carum carvi, Lepidium sativum, Nigella sativa, Olea europea, Peganum harmala, Phoenix dactylifera, Rosmarinus officinalis, and Tetraena gaetula [20]. Also in south-eastern Morocco (Tafillalet region), an ethnobotanical study identified 92 medicinal plants used in the treatment of diabetes mellitus, hypertension and cardiovascular diseases. The most frequently cited medicinal plants used for their antidiabetic effects were Ammi visnaga, Artemisia herba-alba, Trigonella foeniculum-graecum, Marrubium vulgare, Nigella sativa, Globularia alypum, Allium sativum, Olea europea, Citrullus colocynthis, Aloe succotrina, Artemisia absinthium, Rosmarinus officinalis, Thymus vulgaris, Eucalyptus globulus, Mentha pulegium, Myrtus communis, Linum usitatissimum and Carum carvi [21].

**Pharmacological and toxicological studies**

Among 255 plant species being used, 120 plants have neither been explored experimentally for antidiabetic activity. They are: Mesembryanthemum theurkauffii, Salsola tetragona, Searsia albida, Searsia tripartita, Eryngium ilicifolium, Pastinaca sativa, Pycnichotis verticillata, Roldofia segetum, Apteranthus europaea, Periplaca laevigata subsp. Angustifolia, Aristolochia fontanesii, Agave americana, Asparagus albus, Achillea odorata, Antennaria dioica, Anvillea garcinii subsp. radiata, Artemisia abrotanum, Artemisia atlantica, Artemisia mesatlantica, Artemisia reptans, Centaurea maroccana, Cladanthus arabicus, Cynara cardunculus, Ditrichia viscosa, Echinops spinosissimus, Inula conyza, Inula heli enium, Launaea arborescens, Pallenis spinosa, Scalymus hispanicus, Scorzonera undulata, Sonchus arvensis, Sonchus tenerrimus, Tanacetum vulgare, Berberis vulgaris subsp. australis, Diplotaxis pitardiana, Erucia vesicaria, Ptilotrichum spinosum, Buxus balearica, Maerua crassfolia, Herniaria glabra, Silene vivianii, Cistus albidus, Cistus creticus, Cistus salviifolius, Androcymbium gramineum, Juniperus thurifera, Tetraclinis articulata, Cynomorium coccineum, Bolboschoenus maritimus, Dra caena draco subsp. ayal, Ephedra alata, Ephedra altissima, Euphorbia officinarum subsp. echinus, Euphorbia officinarum subsp. officinarum, Hammadra scoparia, Euphorbia resinifera, Mercurialis annua, Anagryris fœtida, Ceratonia siliqua, Cicer arietinum, Lupinus angustifolius, Lupinus luteus, Ononis natrix, Ononis tournefortii, Retama sphaeroarpa, Vicia faba, Vicia sativa, Quercus coccifera, Juncus maritimus, Ballota hirsuta, Clinopodium alpinum, Clinopodium nepeta subsp. glandulosum, Lavandula dentata, Lavandula maroccana, Lavandula multifida, Mentha pulegium, Mentha spicata, Origanum compactum, Origanum majorana, Origanum vulgare, Thymus algeriensis, Thymus munitianus, Thymus zygis, Corrigiola litoralis subsp. telephifolia, Fumaria officinalis, Papaver rhoeas, Globularia repens, Limonium sinuatum, Avena sativa, Castellia tuberculosa, Panicum milieaceum, Panicum turgidum, Polygogon monspeliensis, Triticum durum, Emex spinosa, Fragaria vesca, Rubus vulgaris, Rubia tinctorum, Salix alba, Illicium verum, Taxus baccata, Thymelaea tartonaira, Thymelaea virgata, Aloysia citriodora, Aloe succotrina, Asphodelus microcarpus, Mesembryanthemum theurkaufii, Cladanthus scariosus, Paronychia argentea, Ephemera fragilis, Glycerihiza glabra, Origanum elongatum, Thymus broussetii, Avena sterilis, Lolium perenne, Malus communis, Verbena officinalis, Asphodelus tenuifolius and Tetraena gaetula. It is essential to study the effects of unexplored plant species on diabetes in more detail and to identify the active components and especially to study the mechanisms of action of these plant extracts, in order to obtain further data on the pharmacological effects of these plants.

Despite the therapeutic effects of medicinal plants, excessive consumption of some of the inventoried plants might lead to harmful effects which are related to a variety of causes. To avoid danger to patients, prudent use as well as safety precautions is required, such as using lower doses. The main toxic plants are, Citrullus colocynthis [32], Da tura stramonium [33], Euphorbia officinarum [34], Myristica fragrans [35], Artemisia herba alba [36], Peganum harmala [37], Ricinus communis [38], Tetraena gaetula [39], Nigella sativa [40] and Nerium oleander [32]. Despite their toxic properties, patients do not suffer any adverse consequences. This indicates that the patients or the provider of the plants are skilled in recognizing the potential for toxicity and taking the appropriate precautions.

Of all medicinal plants reported in this study, 137 medicinal plants have been documented to demonstrate a potent anti-diabetic effect in vitro or in vivo or in clinical studies. We present in Table 2 pharmacological studies which have investigated directly or indirectly medicinal plants used in Morocco to treat diabetes. Trigonella foenum-graecum, Artemisia herba-alba, Nigella sativa, Olea europea, Allium cepa and Marrubium vulgare were the most frequently used plants to treat diabetes based on number of citations. These plants are discussed in detail below.
| Family            | Plant species                      | Vernacular name | Plant extracts used | Dose (s) used | Models used in the study | Results                                                                                                                                                                                                 | References |
|-------------------|-----------------------------------|-----------------|--------------------|--------------|--------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Amaranthaceae     | Anabasis aretioides Moq. et Coss. ex Bunge | Chajra ma yeharrekha rith/Vellii | Aqueous extract of aerial part | 5 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Significant reduction on blood glucose levels in STZ rats ($p < 0.0001$)                                                                 | [41]       |
| Amaranthaceae     | Atriplex halimus L.                | Legtef          | Aqueous extract of the leaves | 200 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Aqueous extract produced 54% ($P < 0.001$) decrease in fasting blood glucose levels compared to the initial fasting blood glucose levels prior to the treatment                                            | [42]       |
| Amaranthaceae     | Dysphania ambrosioides (L.) Maysia & Clemants Mkhinza | Mikhinza        | Crude extract of the leaves | 100, 200 and 300 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Reduction in blood glucose in case of crude treatment groups, as compared with that of the control group                                                                                                  | [43]       |
| Amaranthaceae     | Allium ampeloprasum L.             | Borro           | Essential oils from the green parts | 150 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The essential oil of A. ampeloprasum decreased the blood glucose level significantly ($P < 0.005$) at the dose of 200 mg/kg.                                                                                  | [44]       |
| Amaranthaceae     | Allium cepa L.                     | Basla           | Aqueous extracts of the whole plant | 200, 250 or 300 mg/kg BW | Alloxan- induced diabetic rats | A. cepa at 200 mg/kg reduced fasting blood glucose levels by 62.9% (292.3 ± 250 to 108.2 ± 46), at 250 mg/kg it reduced fasting blood glucose levels by 69.7% (296.3 ± 178 to 89.8 ± 43) whereas at 300 mg/kg it reduced it by 75.4% (297.8 ± 375 to 73.4 ± 3.0) | [45]       |
| Amaryllidaceae    | Allium sativum L.                  | Tisket / Touma   | Aqueous extract of the bulbs | 500 mg / kg BW | Streptozotocin-induced diabetic rats (STZ) | At weeks 2, 5 and 7 of garlic extract treatment, the serum glucose levels of the garlic-treated diabetic rats were reduced by 29%, 68% and 57%, respectively in comparison to control diabetic rats. | [46]       |
| Anacardiaceae     | Pistacia atlantica Desf.           | Btem/Igg/Drou   | N-hexane extract of the seeds | 200 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The administration of P. atlantica extracts body wt. tended to bring the blood glucose significantly toward normal values from the beginning of the experiment                                                                 | [47]       |
| Anacardiaceae     | Pistacia lentiscus L.              | Trou/Tidekt     | Crude gum           | 100 mg / kg BW | Alloxan- induced diabetic rats | After 6 h, there was decreased in blood glucose (280.8 ± 9.0) but after 24 h crude Pistacia gum showed significant decrease(195.2 ± 23.6) as compared to diabetic untreated rats (352.4 ± 23.6) | [48]       |
| Apiaceae          | Ammi visnaga (L.) Lam.             | Barhanisse      | Aqueous extract of fruits | 20 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Significant decrease of blood glucose in normal rats 6 h after a single oral administration ($P < 0.005$) and 9 days after repeated oral administration ($P < 0.05$).                                               | [49]       |
| Apiaceae          | Ammodaucus leucotrichus Coss.      | Kamoun soufi    | Aqueous extract of fruits | 10 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Significant reduction in blood glucose levels after four ($p < 0.01$) and 6 h ($p < 0.001$) of treatment. This effect was more pronounced than glibenclamide which caused a significant decrease in blood glucose at the fourth ($p < 0.05$) and sixth ($p < 0.01$) hour after oral administration | [50]       |
| Apiaceae          | Apium graveolens L.                | Krafliss        | Hexane, chloroform and methanol extracts of stalk and leaves | 100, 200 and 400 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Maximum percentage of blood glucose reduction in normoglycemic mice at 8 h with 400 mg/kg doses of chloroform extract was 37%. However, hexane extract and methanol extract at the same doses produce only a small effect | [51]       |
| Apiaceae          | Carum carvi L.                     | Likanwa         | Ethanolic extract of the seeds | 0.2, 0.4 and 0.6 g/kg BW | Streptozotocin-induced diabetic rats (STZ) | Significantly decreased serum glucose and insulin in diabetic rats in 3 and 5 h but not in healthy rats.                                                                                                  | [52]       |
**Table 2**: In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco (Continued)

| Family          | Plant species                      | Vernacular name | Plant extracts used                      | Dose (s) used | Models used in the study                  | Results                                                                                                                                                                                                 | References |
|-----------------|-----------------------------------|-----------------|------------------------------------------|---------------|-------------------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Apiaceae        | Coriandrum sativum L.             | Kosbor          | Aqueous extract of fruits                | 250 and 500 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The aqueous extract of fruits decreased the blood glucose level statistically significant when compared with diabetic control                                                                 | [53]       |
| Apiaceae        | Cuminum cyminum L.                | Kamoun          | Ethanolic extract of the seeds           | 250 mg / kg BW | Streptozotocin-induced diabetic rats (STZ) | Around 17.7% and 17.1% decline in blood glucose levels at 0–300 and 0–1440 min, respectively, on streptozotocin-induced diabetic rats                                                                 | [54]       |
| Apiaceae        | Daucus carota L.                  | Khizou          | Alcoholic extract of the seeds           | 100, 200, 300 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The administration of D. carota seeds extract (300 mg/kg) for 3 days decreased glucose serum level \( (p < 0.05) \)                                                                                  | [55]       |
| Apiaceae        | Foeniculum vulgare Mill.          | Nafaa           | Essential oil extracted from the whole plant | 30 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Ingestion of essential oil corrected the hyperglycemia from \((162.5 \pm 3.19 \text{ mg/dl})\) to \((81.97 \pm 1.97 \text{ mg/dl})\) with \( p < 0.05 \)                                      | [56]       |
| Apiaceae        | Petroselinum crispum (Mill.)      | Maadnouss       | Aqueous extract of the leaves            | 2 g/kg BW     | Streptozotocin-induced diabetic rats (STZ) | Diabetic rats showed a gradual reduce in blood glucose levels over days 14—42. Maximum reduction in the blood glucose levels was observed on the day 42, and the reduction was about 50%                                         | [10]       |
| Apiaceae        | Pimpinia anisum L.                | Habbat hlaawa   | Different fractions of methanolic extract (hexane, benzene, ethyl acetate, n-butanol, aqueous) | 100, 200, 300, 400 and 500 \( \mu \text{g/ml} \) | \( \alpha \)-amylase and \( \alpha \)-glucosidase inhibition enzyme | At the concentration of 500 \( \mu \text{g/ml} \), the sequence of inhibitory effects on \( \alpha \)-amylase and \( \alpha \)-glucosidase activities respectively had the order as follows: Ethyl acetate \((94\% \text{ and } 87\%)\) > hexane \((93\% \text{ and } 86\%)\) > benzene \((91\% \text{ and } 85\%)\) > methanol \((84\% \text{ and } 83\%)\) > aqueous \((81\% \text{ and } 79\%)\) > n-butanol \((75\% \text{ and } 77\%)\). | [57]       |
| Apocynaceae     | Calotropis procera (Alton) Dryand. | Turja           | Chloroform extract of leaves and flowers | 10, 20 and 50 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The reduction in serum glucose levels was better on the 21st and 27th days of treatment                                                                 | [58]       |
| Apocynaceae     | Calotropis procera (Guss.) N.E.Br. | Daghmous        | Methanolic extract of the aerial parts   | 250, 300 mg / kg BW | Alloxan-induced diabetes in mice | The methanolic extract exhibited a continuous marked reduction of blood glucose levels \((p < 0.001)\) particularly \( 6–10 \) h after treatment in diabetic mice                                                                 | [59]       |
| Apocynaceae     | Nerium oleander L.                | Dejla/Allili    | Methanolic extract of the leaves         | 50 and 200 mg/kg BW | Alloxan-induced diabetes in mice | Glucose level was lowered from \( 255.66 \pm 1.52 \text{ mg/dl} \) on day 0 to \( 67.00 \pm 6.24 \text{ mg/dl} \) in day 20, accounting for a significant \((p < 0.001)\) \( 73.79\% \) decrease | [60]       |
| Arecaceae       | Calotropis humilis L.             | Dum /Tiguedden / Ignaadd | Aqueous extract of the leaves            | 10 mg / kg BW | Experimentally induced obesity, hyperglycemia and hyperlipidemia \((\text{OHH})\) in rats | The plasma glucose levels of the \((\text{OHH})\) rats decreased significantly with daily dosing with the plant-extract \((\text{from baseline} 12.04 \pm 0.94 \text{mM/L to} 6.10 \pm 0.27 \text{mM/L} (p < 0.05))\) after 15 days, and to \((4.84 \pm 0.22 \text{mM/L} (p < 0.001))\) after 30 days | [61]       |
| Arecaceae       | Hyphaene thebaica (L.) Mart.      | Dum/Karur       | Aqueous suspension of the pulp           | 1 g/kg BW     | Streptozotocin-induced diabetic rats (STZ) | Significant reduction on blood glucose levels in STZ rats \((p < 0.05)\)                                                                                                                                  | [62]       |
| Arecaceae       | Phoenix dactylifera L.            | Tmar            | Ethanolic extract of the leaves          | 100, 200 and 400 mg/kg BW | Alloxan- induced diabetic rats | A significant antidiabetic effect at 400 mg/kg was observed starting from the 6th day onwards \((p < 0.05)\), and from 10th days onwards for 200 mg/kg | [63]       |
| Brassicaceae    | Anastatica hierochuntica L.       | Chajarat         | Water extract of the aerial parts        | 12.5 mg/rat | Streptozotocin-induced diabetic rats (STZ) | The administration of the plant extract induced a hypoglycemic effect in both non-glycemic and diabetic rats. It also caused significant improvement in tissue injury induced by STZ                                                                 | [64]       |
| Brassicaceae    | Brassica napus L.                 | Left            | Hydro-alcoholic extract                  | 16 ml/ kg BW | Alloxan- induced diabetic rats            | Significantly decrease of blood glucose compared to diabetic control rats \((p < 0.05)\)                                                                                                                   | [65]       |
| Brassicaceae    | Brassica nigra (L) K.Koch          | Elkhardel       | Chloroform, acetone, ethanol and aqueous extracts of the seeds | 200 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The administration of aqueous extract daily once for 1 month brought down fasting serum glucose levels                                                                                               | [66]       |
Table 2: In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco (Continued)

| Family      | Plant species          | Vernacular name                  | Plant extracts used                                      | Dose(s) used | Models used in the study              | Results                                                                 | References |
|-------------|------------------------|----------------------------------|----------------------------------------------------------|--------------|---------------------------------------|------------------------------------------------------------------------|------------|
| Brassicaceae| Brassica oleracea L.   | Krunb, mkawar/melfuf             | Different fractions (Petroleum ether, ethyl acetate and chloroform) of ethanolic extract of the leaves | 150 mg/kg BW | Alloxan-induced diabetic rats         | Significant reduction on blood glucose levels (P < 0.05)                 | [67]       |
| Brassicaceae| Brassica rapa L.       | Left beldi                       | Aqueous extract of the leaves                            | 200 and 400 mg/kg BW | Alloxan-induced diabetic rats         | Both doses significantly decreased (P < 0.001) blood glucose levels in diabetic rats after 28 days of administration | [68]       |
| Brassicaceae| Lepidium sativum L.    | Habi errechad                    | Seed powder                                              | 3 g / kg BW  | Alloxan-induced diabetic rats         | Significant decrease (P ≤ 0.05) in fasting blood glucose levels         | [69]       |
| Brassicaceae| Nasturtium officinale R.Br. | Gernunes | Hydroalcoholic extract of the leaves                    | 100 and 200 mg/kg BW | Streptozotocin-induced diabetic rats(STZ) | Treatment of diabetic rats for 4 weeks with Nasturtium officinale extract significantly decreased their serum glucose levels | [70]       |
| Brassicaceae| Raphanus sativus L.    | Lfjel                            | Root juice                                               | 100, 200, 300, and 400 mg/kg BW | Streptozotocin-induced diabetic rats(STZ) | Maximum reduction of 15.9% (p < 0.001) in blood glucose level at 3 h in normal rats, whereas the reduction observed was by 23.8 and 28.3% (p < 0.001) in sub- and mild-diabetic rats, respectively | [71]       |
| Buxaceae    | Buxus sempervirens L.  | Libeis                           | Aqueous extract of the leaves                            | 5 mg/kg BW   | Streptozotocin-induced diabetic rats(STZ) | The aqueous extract reduced the blood glucose of both healthy and diabetic rats. This extract was also able to improve oral glucose tolerance in diabetic rats and it ameliorated hepatic histology | [72]       |
| Cactaceae   | Opuntia ficus indica (L.) Mill. | Lhndia/ Aknati                  | Water extract of the whole plant                         | 100 mg/kg BW | Streptozotocin-induced diabetic rats(STZ) | Significantly decrease of blood glucose compared to diabetic control rats (P < 0.05) | [73]       |
| Capparaceae | Capparis decandra (Forsk.) Edgew. | Ignin                           | Aqueous and ethanolic extract of the stem                | 250 and 500 mg/kg BW | Alloxan-induced diabetic rats         | The fasting blood glucose level decreases by 58.5, 83.6% (aqueous extract) and 60.2, 98.5% (ethanolic extract) after 21st day in diabetic rats treated with a different doses of 250 mg and 500 mg/kg BW respectively | [74]       |
| Capparaceae | Capparis spinosa L.    | Kabar/Tayulut                    | Hydroalcoholic extract of the root                       | 0.2 and 0.4 g/kg BW | Streptozotocin-induced diabetic rats(STZ) | Glucose levels significantly decreased after treating with plant extract (p = 0.003) | [75]       |
| Cistaceae   | Cistus laurifolius L.  | Agullid                          | Aqueous and ethanolic extracts of the leaves             | 250 and 500 mg/kg BW | Streptozotocin-induced diabetic rats(STZ) | The blood glucose levels of the STZ-induced diabetic rats were decreased by ethanolic extract as compared to control group (16%–34%) | [76]       |
| Compositae  | Anacyclus pythium (L.) Lag. | Iguntas/Tagundechte               | Aqueous extract of the roots                            | 150 and 300 mg/kg BW | Alloxan-induced diabetic rats         | The significant reduction (p < 0.01) of blood glucose was observed at 60 and 120 min of the experiment | [77]       |
| Compositae  | Artemisia absinthium L. | Chiba                            | Ethanol extract of the whole plant                       | 250, 500 and 1000 mg/kg BW | Alloxan-induced diabetic rats         | A time-dependent significant hypoglycemic activity in medium dose (500 mg/kg BW, P < 0.01) and high dose (1000 mg/kg BW, P < 0.001), which was clearly after day 10 treatment period | [78]       |
| Compositae  | Artemisia herba-alba Asso | Izvi/Chih dwidi                  | Aqueous extract of the aerial parts                      | 0.39 g/kg BW  | Alloxan-induced diabetic rats         | The administration of Artemisia herba-alba indicates significant (P < 0.05) reduction of blood glucose concentration and was found to be antidiabetic | [79]       |
| Compositae  | Chamæamelium nobil (L.) All. | Babounj                        | Aqueous extract of the aerial parts                      | 20 mg/kg BW   | Streptozotocin-induced diabetic rats(STZ) | The blood glucose levels were decreased from 6.1 ± 0.06 mmol/l to 4.6 ± 0.17 mmol/l (P < 0.01) and from 21.1 ± 1.31 mmol/l to 13.7 ± 0.90 mmol/l (P < 0.01) in normal and STZ diabetic rats, respectively, after 15 days of treatment. | [80]       |
| Compositae  | Ochotum intybus L.     | Buaggad                         | Ethanol extract of the whole plant                       | 125 mg / kg BW | Streptozotocin-induced diabetic rats(STZ) | The daily administration for 14 days to diabetic rats attenuated serum glucose by 20%, triglycerides by 91% and total cholesterol by 16% | [81]       |
| Family          | Plant species         | Vernacular name | Plant extracts used                  | Dose (s) used | Models used in the study                             | Results                                                                 | References |
|-----------------|-----------------------|-----------------|--------------------------------------|--------------|-----------------------------------------------------|------------------------------------------------------------------------|------------|
| Compositae      | Lactuca sativa L.     | Khes            | Lactucaxanthin isolated from Lactuca sativa | 6.854 μg     | α-Amylase and α-glucosidase assays using streptozotocin-induced diabetic rat models | Lactucaxanthin significantly inhibited (p < 0.05) the activity of α-amylase and α-glucosidase | [82]       |
| Compositae      | Matricaria chamomilla L. | Mansania       | Aqueous extract of the leaves        | 200 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)           | The administration of Matricaria chamomilla once daily for 21 days reduced the elevated Fasted Blood Glucose by 62.2% (p < 0.001) | [83]       |
| Compositae      | Taraxacum campylodes G. Eh Hlg Bund | Lhandba       | Aqueous extract and methanol extract of roots, flowers and stems | 20, 40, 60, 80 and 100 μg/ml | α-glucosidase and α-amylase enzyme inhibiting activity | The stem showed the highest overall inhibitory effect of both (alpha amylase + alpha glucosidase) as an average of about 87.2% | [84]       |
| Compositae      | Watsonia saharea Bentham ex. Benth & Coss. | Afssas         | Aqueous extract of the aerial parts  | 5 mg/kg BW    | Streptozotocin-induced diabetic rats (STZ)           | The blood glucose levels were decreased in normal and STZ-induced diabetic rats after 15 days of treatment | [85]       |
| Cucurbitaceae   | Citrullus colocynthis (L.) Schrad. | Afrersiz/lnde | Chloroform, ethanol and aqueous extracts of the root | 200 mg/kg BW | Alloxan- induced diabetic rats                       | Aqueous extract showed significant reduction in blood sugar level (58.70%) when compared with chloroform (34.72%) and ethanol extracts (36.60%) (p < 0.001) | [86]       |
| Cucurbitaceae   | Cucumis sativus L.    | Lkhiar          | Ethanol extract of the fruit         | 200 and 400 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The hyperglycemia was significantly (P < 0.05) lowered by the administration of 200 mg/kg and 400 mg/kg body weight ethanol extract | [87]       |
| Cucurbitaceae   | Cucurbita maxima Duchesne | Garaa Ihamra   | Petroleum ether, ethyl acetate and alcohol extract of the seeds | 200 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)           | The blood glucose concentration was significantly (P < 0.05) decreased compared to control | [88]       |
| Cucurbitaceae   | Cucurbita pepo L.     | Takhsats/curj  | Fruit powder                         | 2 g/kg BW    | Alloxan- induced diabetic rats                       | Significantly decrease of blood glucose compared to diabetic control rats (P < 0.05) | [89]       |
| Cupressaceae    | Juniperus phoenicea L. | Araar finiqui   | Essential oil, hexane and methanol extracts of the leaves | 50, 100 and 200 μg/mL | α-Amylase inhibition assay | The IC50 values of essential oil, hexane and methanol extracts against α-amylase were 35.44, 30.15 and 53.76 μg/mL, respectively, and those against pancreatic lipase were 66.15, 68.47 and 60.22 μg/mL respectively | [90]       |
| Cyperaceae      | Cyperus rotundus L.   | Tara            | Hydro-ethanolic extract of the tubers | 200 and 500 mg/kg BW | Alloxan- induced diabetic rats                       | This hyperglycemia was significantly (P < 0.05) lowered by the administration of Hydro-ethanolic extract | [91]       |
| Ericaceae       | Arbutus andro L.      | Sasnu           | Water extract of the roots           | 500 mg/kg BW | Oral glucose tolerance test in rats (OGTT)          | The water extract produced a decrease of glyceremia at 1 h and 3 h after glucose loading (21.1%, p < 0.05 and 14.1%, p < 0.05, respectively) | [92]       |
| Euphorbiaceae   | Ricas communis L.     | Awriwe/Likhawa  | Ethanolic extract of the root        | 125, 250, 500, 750, 1000 and 2000 mg/kg BW | Alloxan- induced diabetic rats | Five-hundred milligram per kilogram body weight appeared to be the effective dose as it caused the maximum lowering of the fasting blood glucose | [93]       |
| Leguminosae     | Vigna radiata (L.) R.Wilczek | Soja           | Raw, boiled, and sprouted mung beans | Not mentioned | α-amylase and α-glucosidase inhibition enzyme | α-amylase and α-glucosidase inhibitory activities were higher (p < 0.05) in sprouted mung compared to raw mung and boiled mung. | [94]       |
| Leguminosae     | Vigna unguiculata (L.) Wolp | Ful gnawa      | Seed oil                            | 100 and 200 mg/kg BW | Alloxan- induced diabetic rats                       | Significant reduction in blood glucose level was noted and at the dose of 200 mg/kg.b.wt serum glucose level was found to be very close to the non-diabetic control | [95]       |
| Family      | Plant species          | Vernacular name | Plant extracts used                        | Dose (s) used | Models used in the study | Results                                                                 | References |
|------------|------------------------|-----------------|--------------------------------------------|---------------|--------------------------|-------------------------------------------------------------------------|------------|
| Gentianaceae | Centaurium etytraeae Rafn | Quset elhayya / Achrif ntawma | Aqueous and butanolic extracts of the aerial parts | 0.015 ml / 100 g and 0.66 ml / 100 g BW | Oral glucose tolerance test overload “OGTT” | The administration of extracts has reduced significantly glycaemia compared to controls at 160, 190, 120 and 1180 min | [96]       |
| Iridaceae  | Crocus sativus L.      | Zaafan Ithor   | Ethanol Extract of stigma                  | 20, 40 and 80 mg/kg BW | Alloxan- induced diabetic rats | The dose of 40 mg/kg was found to be more effective dose in intraperitoneally route for decreasing blood glucose level | [97]       |
| Juglandaceae | Juglans regia L.       | Swak / Gargaa  | Alcoholic extract of the leaves            | 200 and 400 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The extract reduced the hyperglycemia significantly compared to control group (P < 0.05) | [98]       |
| Lamiaceae  | Ajuga ka (L.) Schreib. | Timina naenkhah / Chndkoura | Lyophilised aqueous extract of the whole plant | 10 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Significant reduction in blood glucose level in normal rats as compared to the untreated groups and to the pre-treatment levels (0 h) (793.96 mg/dl at 6 h vs 100.73.34 mg/dl at 0 h, P < 0.01) | [99]       |
| Lamiaceae  | Lavandula angustifolia Mill | Elkhzama zeraq / Elkhzama Fassiya | Methanolic extract of the whole plant       | 125–400 µg/ml | Inhibitory effects on both hormone sensitive lipase (HSL) and pancreatic lipase (PL) | The extract inhibited HSL activity in a dose dependent manner with an IC50 of 175.5 µg/ml | [100]      |
| Lamiaceae  | Lavandula stoechas L.  | Imizra / Tikenkert / Lhalhal | Essential oil extracted from the aerial parts | 50 mg / kg BW | Alloxan- induced diabetic rats | Lavandula stoechas essential oils significantly protected against the increase of blood glucose | [101]      |
| Lamiaceae  | Marrubium vulgare L.   | Mrriwfis   | Methanolic extract of the aerial parts     | 500 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | A highly significant reduction in the plasma glucose level starting at the 14th day of treatment, compared to before treatment (day 0) | [102]      |
| Lamiaceae  | Ocimum basilicum L.    | Lahbaq     | Aqueous extract of the leaves              | 20, 18.2, 16.3 and 14.5 mg/ml | α-amylase and α-glucosidase inhibition enzyme | The aqueous extract showed strong α-glucosidase and α-amylase inhibiting activities | [103]      |
| Lamiaceae  | Rosmarinus officinalis L. | Azir | Ethanolic extract of the leaves            | 50, 100 and 200 mg/kg BW | Alloxan-diabetic rabbits | The highest dose (200 mg/kg) significantly lowered blood glucose level and increased serum insulin concentration in alloxan-diabetic rabbits | [104]      |
| Lamiaceae  | Salvia officinalis L.  | Salmia     | Ethanolic extract of the leaves            | 0.1, 0.2, and 0.4 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The effect of administration of extract and glibenclamide tended to bring serum glucose and insulin towards normal values | [105]      |
| Lamiaceae  | Teucrium polium L.     | Tawerart / Flyou Ibour / Jaajia | Aqueous decoction of the aerial parts       | 5 ml (20% w/v) | Streptozotocin-induced diabetic rats (STZ) | Significant reductions in blood glucose concentration 4 h after intravenous administration and 24 h after intraperitoneal administration | [106]      |
| Lamiaceae  | Thymus satureioides Coe. | Asserka / Zitla | Aqueous extract of the aerial parts         | 500 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | Administration of aqueous extract to diabetic rats for 28 d reduced their fasting blood glucose levels significantly compared to the diabetic control rats | [107]      |
| Lamiaceae  | Thymus vulgaris L.      | Aduchen / Azulki / Zitla | Methanol, ethanol and aqueous extract of the whole plant | 2, 4, 8, 10, 15 µg/ml | α-amylase and α-glucosidase inhibition enzyme | The results of anti-diabetic activity produced by Thymus vulgaris showed that the volatile compounds were effective to α-glucosidase and α-amylase inhibition. | [108]      |
| Lauraceae  | Cinnamomum cassia (L.) J.Presl | Qarfa | Aqueous extract of the bark                 | 60 mg/kg BW | Alloxan- induced diabetic rats | A highly significant (P < 0.001) decrease in mean fasting blood glucose level, 203.5 ± 13.47 on 10th and 191.5 ± 12.72 on 15th day as compared to mean fasting blood glucose level | [109]      |
| Family       | Plant species                          | Vernacular name | Plant extracts used              | Dose (s) used | Models used in the study                                      | Results                                                                                           | References |
|--------------|----------------------------------------|-----------------|----------------------------------|---------------|----------------------------------------------------------------|---------------------------------------------------------------------------------------------------|------------|
| Lauraceae    | Cinnamomum verum J.Presl              | Dar essini      | Aqueous extract of the bark      | 200, 400, 600 and 1200 mg/kg BW | Alloxan-induced diabetic rats                                   | After 30 days, the administration of diabetic rats with the lowest dose (200 mg/kg BW) of extracts was the most efficient in affecting significant (P < 0.05) reduction in the levels of fasting blood glucose | [110]      |
| Lauraceae    | Laurus nobilis L.                      | Ourak sidna moussa/Rand | Essential oil and its three main components | 0.606 to 1.300 μL/mL | α-glucosidase inhibition enzyme                                | Essential oil was found to inhibit α-glucosidase over 90%. The IC50-value of the oil was determined to be 1.748 ± 0.021 μL/mL | [111]      |
| Lauraceae    | Persa americana Mill.                  | Lavoca          | Aqueous extract of the seeds     | 20, 30, 40 g/l | Alloxan-induced diabetic rats                                   | The extract possessed a significant hypoglycaemic (P < 0.05) in alloxan-induced diabetic rats, comparable to the effect of glibenclamide | [112]      |
| Leguminosae  | Acacia nilotica (L.) Delile            | Amur/Silaha     | Aqueous methanolic extract of pods | 200, 300 and 400 mg/kg BW | Alloxan-induced diabetic rabbits                                | A dose of 400 mg/kg BW maximally reduced the blood glucose levels as compared to the diabetic group (P < 0.001). | [113]      |
| Leguminosae  | Acacia senegal (L.) Willd.             | Laalek          | Ethyl acetate extract of stem bark | 200 and 400 mg/kg BW | Alloxan-induced diabetic rats                                   | In diabetic rats, both the doses (200 mg/kg and 400 mg/kg) of ethyl acetate extract were found to be significantly (P < 0.05) active in comparison to control | [114]      |
| Leguminosae  | Acacia tortilis (Forsk.) Hayne         | Tellit/ Tadoute | Aqueous extract of the leaves    | 800 mg/kg BW  | Diagnostic kits Spectrophotometrically in rats                 | The administration of aqueous extract for seven consecutive days caused significant (P < 0.05) decrease in blood glucose | [115]      |
| Leguminosae  | Arachis hypogaea L.                    | Lgerta/Kawkw    | Aqueous extract of the seeds     | 2 ml          | Alloxan-induced diabetic rats                                   | The extract caused a significant (P < 0.05) decrease of fasting blood glucose of both normal and alloxan-induced diabetic rats | [116]      |
| Leguminosae  | Faidherbia albida (Delile) A.Chev.     | Chok/Talhi/Mimouza | Aqueous extract of stem bark     | 125, 250 and 500 mg/kg BW | Alloxan-induced diabetic rats                                   | The aqueous extract possessed anti-hyperglycemic effect in alloxan induced diabetic rats | [117]      |
| Leguminosae  | Glycine max (L.) Merr.                 | Soja            | Petroleum ether, alcoholic and aqueous extract of seeds | 100, 200 and 400 mg/kg BW | Alloxan-induced diabetic rats                                   | The antihyperglycemic effect of aqueous extract showed onset at the 2nd h; peak effect at the 4th h and the antihyperglycemic effect was sustained till the 24th h | [118]      |
| Leguminosae  | Lupinus abus L.                        | Tirma/Foulgnawa | Aqueous extract of seed coat     | 18.4 and 36.8 mg/kg BW | Glucose Resistant Mice                                          | Decrease in blood glucose at 30 min relative to control, but this difference was not significant for either concentration | [119]      |
| Leguminosae  | Medicago sativa L.                     | Fassa           | Aqueous extract of seeds         | 7 mg/100 g BW  | Alloxan-induced diabetic rats                                   | The aqueous extract has hypoglycemic effect by increasing insulin level and decreasing insulin resistance | [120]      |
| Leguminosae  | Phascolus vulgaris L.                  | Lubya           | Seeds                           | 100, 200 and 300 mg/kg BW | Induction of hyperglycemia in rats by administration of glucose | Seeds of P. vulgaris at a dosage of 300 mg/kg bw is showing maximal blood glucose lowering effect in diabetic rats after third hour | [121]      |
| Leguminosae  | Retama rams (Forsk.) Webb              | Rtam/Allug      | Methanolic extract of the fruits | 100, 250 and 500 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)                      | The extracts at 250 or 500 mg/kg significantly lowered blood glucose levels at the 3rd and 1st week of treatment, respectively | [63]       |
| Leguminosae  | Trigonella foenum-graecum L.           | Lhelba/Tifidas  | Alcoholic extract of the seeds   | 1, 2, and 4 g  | Alloxan-induced diabetic rats                                   | Significant reduction on blood glucose levels was seen with alcoholic extract (743 ± 4.77 to 60.56 ± 1.9 in normal rats and 201.25 ± 7.69 to 121.25 ± 6.25 in diabetic rats) (P < 0.001) | [122]      |
| Linaceae     | Unum usitatissimum L.                  | Zariat elkattan | Ethanolic extract of the seeds   | 200 and 400 mg/kg BW | Alloxan-induced diabetic rats                                   | The extract significantly reduced serum glucose level. The antihyperglycaemic effects showed onset at 4th h (P < 0.001) and peak effect at 6th h (P < 0.001) | [123]      |
| Lythraceae   | Lavandula inermis L.                   | Lhenna           | Ethanolic extract of the whole plant | 150, 300 and 500 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)                      | Significantly decreased level of blood glucose. The effect of dose 0 500 mg/kg BW was found to be better then 150 and 300 mg/kg BW | [124]      |
| Family       | Plant species                        | Vernacular name | Plant extracts used                      | Dose (s) used       | Models used in the study                           | Results                                                                                                                                                                                                 | References |
|--------------|--------------------------------------|-----------------|------------------------------------------|---------------------|---------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Lythraceae   | Punica granatum L.                   | Rman            | Ethanol extract of the leaves            | 500 mg/kg BW        | Alloxan-induced diabetic rats                     | Significant decrease (P < 0.01) in blood glucose level in comparison to control group                                                                                                                         | [125]      |
| Malvaceae    | Abelmoschus esculentus (L.) Moench  | Lmloukhia       | Peel and seed powder                     | 100 and 200 mg/kg BW| Streptozotocin-induced diabetic rats (STZ)         | Significant (P < 0.001) reduction in blood glucose level and increase in body weight than diabetic control rats                                                                                                    | [126]      |
| Malvaceae    | Hibiscus sabdariffa L.               | Karkadi/Bissam  | Aqueous extracts of the calyces         | 10-80 μg/mL         | α-amylase and α-glucosidase inhibition enzyme      | The extracts caused inhibition of α-amylase and α-glucosidase activities in vitro                                                                                                                      | [127]      |
| Moraceae     | Ficus carica                         | Tazart/Karmous/Karma/chriha/Elbakur | Aqueous extract of the leaves          | 2.5 g/100 ml        | Streptozotocin-induced diabetic rats (STZ)         | The extract decreased (p < 0.025) plasma glucose in diabetic (27.9 ± 4.5 mmol/L to 19.6 ± 9.9 mmol/L) while not in normal rats                                                                                     | [128]      |
| Moraceae     | Morus alba L.                        | Tut lbari       | Alcohol extract of the root bark        | 200, 400 and 600 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)       | A significant decline in serum glucose level to a value of 155 mg/dl, P < 0.05 as compared to STZ-diabetic rats                                                                                           | [129]      |
| Musaceae     | Musa × paradisiaca L.                | Banan           | Ethanol extracts of leaves, fruit peels, stems and roots | 100, 250 and 500 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)         | Only leaves and ripe fruit peels showed promising antidiabetic effect                                                                                                                                   | [130]      |
| Myristicaceae| Myristica fragrans Dehnh.            | Logouza         | Petroleum ether extract of the seeds    | 100 and 200 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)         | A significant decrease in blood glucose level from 56.5 ± 3.19 (0 h) to 49.75 ± 205 mg% (4 h) in normoglycaemic rats                                                                                       | [131]      |
| Myrtaceae    | Eucalyptus camaldulensis Dehnh.      | Calitus         | Essential oil extracted from the leaves | 0.10 and 0.25 ml    | α-amylase and α-glucosidase inhibition enzyme      | Both α-amylase and α-glucosidase were inhibited by a non-competitive mechanism                                                                                                                           | [132]      |
| Myrtaceae    | Eucalyptus globulus Labill.          | Calitus         | Aqueous extract of the leaves           | 150 and 300 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)         | The aqueous extract exhibited a significant and dose-dependent effect on the blood glucose levels (P < 0.001). The highest dose (300 mg/kg) produced the most pronounced lowering of blood glucose levels | [133]      |
| Myrtaceae    | Myrtus communis L.                   | Rihane          | Hydroalcoholic, water, and ethanol extracts of the leaves | 2 and g/kg BW      | Streptozotocin-induced diabetic rats (STZ)         | The ethanolic extract of leaves (2g/kg) had a better hypoglycemic effect in diabetic rats compared with the aqueous extract (p < 0.05)                                                                    | [134]      |
| Myrtaceae    | Syzygium aromaticum (L.) Merr. & LMPerry | Kranfal       | Essential oil extracted from the buds and seeds | 1 to 100 μg/mL      | α-amylase inhibition enzyme                       | The maximum antidiabetic activity for S. aromaticum essential oils was noted at the highest dose (100μg/mL).                                                                                               | [135]      |
| Nitrariaceae | Peganum harmala L.                   | Lharmel         | Ethanol extract of the seeds            | 150 and 250 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)         | The oral administration of ethanolic extract causes maximum fall of blood glucose level to 22.9% (p < 0.05) and 29.4% (p < 0.01) respectively with the two doses in normal and 30.3% (p < 0.01) and 48.4% (p < 0.001) in diabetic rats | [11]       |
| Oleaceae     | Fraxinus angustifolia Vahl           | Touzalt         | Hydroalcoholic extracts of leaves and bark | 25 and 50mg/kg BW   | Streptozotocin-induced diabetic rats (STZ)         | A considerable hypoglycemic effect was noticed 2 h after the STZ-induction, with a higher efficiency (P < 0.005) for leaf extract (68%) as compared with bark extract (57%)                                               | [136]      |
| Oleaceae     | Olea europaea L.                     | Jbouj/Azmour/Zitoun | Alcohol extract of the leaves           | 0.1, 0.25 and 0.5 g/kg BW | Streptozotocin-induced diabetic rats (STZ)         | The antidiabetic effect of the extract was more effective than that observed with glibenclamide                                                                                                                | [137]      |
| Family            | Plant species           | Vernacular name | Plant extracts used | Dose (s) used | Models used in the study | Results                                                                                                                                  | References |
|-------------------|-------------------------|-----------------|---------------------|--------------|--------------------------|------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Pedaliaceae       | Sesamum indicum L.      | Janjlan          | Ethanolic extract of the seeds | 500 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | A significant decrease in the elevated blood glucose and increase in the lowered insulin and glycogen levels. | [138]      |
| Plantaginaceae    | Globularia azyum L.     | Ayen Lerneb/Taseligha | Aqueous extract of the leaves | 100 and 20 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | In the diabetic rats, the blood glucose levels was mostly reduced, due to repeated oral treatment of G. azyum leaves (20 mg/kg; P < 0.001). | [139]      |
| Poaceae           | Cynodon dactylon (L.) Pers. | Njem            | Aqueous extract of the whole plant | 250, 500 and 1000 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The dose of 500 mg/kg was identified as the most effective dose. It lowers blood glucose level around 31% after 4 h of administration in normal rats. | [140]      |
| Poaceae           | Hordeum vulgare L.      | Chair/Zraa      | Hydroalcoholic extract of the seeds | 0.1, 0.25, 0.5 g/kg | Streptozotocin-induced diabetic rats (STZ) | The extract at doses of 0.25 and 0.5 g/kg, were only effective in detraction blood glucose levels of diabetic rats after 11 days of continued daily therapy. | [141]      |
| Poaceae           | Pennisetum glaucum (L.) R.Br. | Illan           | Hexane, ethylacetate, methanolic and aqueous extracts of the seeds | 250 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The aqueous extract has shown maximal blood glucose lowering effect in diabetic rats. | [142]      |
| Poaceae           | Phalaris canadinus L.   | Zouan           | Encrypted peptides released after gastrointestinal digestion of seed proteins | 0, 200, 400, 600, 800, 1000, 1200, and 1400 μg/mL | Assay for Inhibitory Activity of Dipeptidyl Peptidase IV | The peptides showed 43.9% inhibition of dipeptidyl peptidase IV. | [143]      |
| Poaceae           | Sorghum bicolor (L.) Moench | Bachna         | Dried extract of the whole plant | 0.4 g/kg BW | Hepatic gluconeogenesis of streptozotocin-induced diabetic rats | The hypoglycemic effect of extract was related to hepatic gluconeogenesis but not the glucose uptake of skeletal muscle, and the effect was similar to that of anti-diabetic medication. | [144]      |
| Poaceae           | Zea mays L.              | Lahyat Adra     | Corn silk aqueous extract | 0.25–100 mg/mL, 0.25–80 mg/mL | Assay for Inhibitory Activity of Dipeptidyl Peptidase IV | In vitro analysis of the extract showed that it exhibited potent and moderate inhibitory potential against α-amylase and α-glucosidase, respectively. The inhibition was concentration-dependent with respective half-maximal inhibitory concentration (IC50) values of 5.89 and 0.93 mg/mL. | [145]      |
| Portulacaceae     | Portulaca oleracea L.    | Rejła            | Aqueous extract of the whole plant | 200 and 400 mg/kg BW | Alloxan-induced diabetic rats | The hypoglycemic effect of extract became significant following oral administration 1 h, reached the peak at 1.5 h (p < 0.01), and was still significant at 4 h | [6]         |
| Ranunculaceae     | Nigella sativa L.        | Haba souda/Sanouj | Hydroalcoholic extract of the seeds | 5, 10, and 20 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | 5 mg/kg BW is the most effective dose for assessing the anti-hyperglycemic potential of hydroalcoholic extract of N. sativa in diabetic rats. | [146]      |
| Rhamnaceae        | Ziziphus lotus (L.) Lam. | Nbeg/Azougar/ssidra | Aqueous extract of leaves and fruits | 250 μL 150 μL | α-amylase and α-glucosidase inhibition enzyme | Z. lotus leaves and fruits, demonstrated inhibitory effects against α-amylase (IC50: 20.40–31.91 μg/mL), and α-glucosidase (IC50: 8.66–27.95 μg/mL). | [147]      |
| Rosaceae          | Cydonia oblonga Mill.    | Sferjel         | Aqueous extract of the fruits | 80, 160, and 240 mg/kg | Streptozotocin-induced diabetic rats (STZ) | The oral administration of the extract prevented diabetes-induced increase in serum urea and creatinine levels as the markers of renal dysfunction. | [148]      |
| Rosaceae          | Chaenomeles sinensis (Dum.Cours.) Koehne | Sferjel | Ethyl acetate fraction from the fruits | 50 and 100 mg/kg BW | Streptozotocin-induced diabetic rats (STZ) | The administration of C. sinensis fruits extract (100 mg/kg BW) restored the blood glucose to almost normal level. | [149]      |
| Rosaceae          | Erionotrya japonica (Thunb.) Lindl. | Mzah          | Alcoholic extract of the leaves | 100, 150 and 200 mg/kg | Alloxan-induced diabetic rats | The extract exerted a significant (P < 0.05) hypoglycaemic effect in normal rabbits which was however short-lived. The hypoglycaemic effect was not significant (P > 0.1) in alloxan-treated rabbits. | [150]      |
| Family   | Plant species                  | Vernacular name | Plant extracts used                                                                 | Dose(s) used | Models used in the study                                                                 | Results                                                                                                                                                                                                 | References |
|----------|--------------------------------|-----------------|--------------------------------------------------------------------------------------|--------------|-----------------------------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|------------|
| Rosaceae | Prunus armeniaca L.           | Luz elhar       | The pomace and the detoxified kernel extract                                          | 4, 6 and 8 mg/kg, 3 and 4 mg/kg | Alloxan-induced diabetic rats                                                              | Pomace extract showed significant (p ≤ 0.05) antidiabetic activity more prominent than the detoxified kernel extract acutely, subchronically and on longer-terms                                             | [151]      |
| Rosaceae | Prunus dulcis (Mill.) D.A. Webb | Louz imrag/ Louz morr | Ethanol extract, ethyl acetate fraction, hexane fraction, chloroform fraction, n-butanol fraction, water fraction and almond oil | Not mentioned | Protein tyrosine phosphatase-1B (PTP1B) inhibition                                         | The alcoholic extract showed strong anti-diabetic (PTP1B inhibition) activity with an IC_{50} 0.46 μg/mL                                                                                              | [152]      |
| Rutaceae | Citrus medica L.               | Lhamed beïdle   | Petroleum ether extract of the. Seeds                                                | 200 and 400 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)                                                 | Significant reduction (p < 0.05) of fasting blood glucose in dose dependent manner after 15 days of drug administration                                                                             | [153]      |
| Rutaceae | Citrus paradisi Macfad.         | Pamblamus       | Phenolic extract from grapefruit peels                                              | 500 mL, 50 mL | Interaction with α-amylase, α-glucosidase, and angiotensin-1-converting enzyme (ACE)      | The phenolic extracts inhibited α-amylase, α-glucosidase and ACE enzyme activities                                                                                                                     | [154]      |
| Rutaceae | Citrus sinensis (L) Odebeck    | Peel ethanolic extract | 250 and 500 mg/kg BW                                                                 | Streptozotocin-induced diabetic rats (STZ) | Diabetic rats treated with 250 and 300 mg/kg of extract showed a significant reduction in blood glucose levels of 11 and 25%, respectively                                                        |                                                                                                                                                                                                            | [155]      |
| Rutaceae | Citrus x aurantium L.          | Larenji/Zentbiel/trunj | The alcoholic extract of fruit peel                                                   | 300 and 500 mg/kg BW | Alloxan-induced diabetic rats                                                              | On repeated administration of ethanolic extract for 21 days, a significant (p < 0.001) dose-dependent decrease in blood glucose of the diabetic rats was seen as compared to control group | [156]      |
| Rutaceae | Ruta graveolens L.             | Lfijel          | Water extract of the whole plant                                                    | 125 and 50 mg/kg BW | Nicotinamide-streptozotocin-induced (type 2) diabetic albino rats                         | Significant amelioration of glucose tolerance                                                                                                                                                           | [157]      |
| Rutaceae | Ruta montana (L) L.            | Lfijel /Iwermi  | Aqueous extract of the aerial parts                                                 | 5 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)                                                 | Both single and repeated oral doses produced significant reductions in the blood glucose levels in normal and STZ-induced rats                                                                          | [158]      |
| Santalaceae | Viscum album L.               | Lenjbar         | Aqueous extract of the leaves                                                        | 100 and 200 mg/kg BW | Alloxan-induced diabetic animals                                                           | Doses of 200 mg/kg and 400 mg/kg BW produced significant (p < 0.05) lowering of blood sugar in fasted normal white albino rats and alloxanized rabbits respectively | [159]      |
| Sapotaceae | Argania spinosa (L) Skeels     | Argan           | Aqueous extract of the fruits                                                        | 10 mg/kg BW | Streptozotocin-induced diabetic rats (STZ)                                                 | Single oral administration reduced blood glucose levels 6 h after administration in STZ diabetic rats. Furthermore, blood glucose levels were decreased in STZ diabetic rats after 7 days of treatment | [160]      |
| Solanaceae | Capsicum annum L.              | Fellel Ham/ soudania | Water extract of nine types of pepper                                                | 500 mL, 50 mL | α-amylase and α-glucosidase inhibition enzyme                                             | Several pepper extracts had high α-glucosidase inhibitory activity. Select extracts such as Green pepper and Long hot pepper had less or no inhibitory effect on the α-amylase activity | [161]      |
| Solanaceae | Datura stramonium L.           |                  | Aqueous extract of the leaves                                                        | 100–1000 μl | α-amylase inhibition enzyme                                                               | The assay carried out on alpha-amylase enzyme showed the dose-dependent increase in inhibitory effect with IC_{50} 730 μg                                                                                 | [162]      |
| Solanaceae | Lycopersicon esculentum Mill.  | Sdag jmel/Metal | The supernatant (juice fraction)                                                     | 0 to 0.8 mg/ml | α-amylase and α-glucosidase inhibition enzyme                                             | Stronger inhibition of α-glucosidase than α-amylase activity                                                                                                                                              | [163]      |
| Solanaceae | Nicotiana tabacum L.           | Nefha           | Acetone, ethanol and water extract of the leaves                                     | 250 μL | α-amylase and α-glucosidase inhibition enzyme                                             | The aqueous extract was most effective inhibitor of α-amylase (IC_{50} 5.7 mg/mL) while acetone extract exhibited the best inhibitory potential on α-glucosidase (IC_{50} 4.5 mg/mL) | [164]      |
Table 2  In vivo and in vitro studies of medicinal plants used in the treatment of diabetes in Morocco (Continued)

| Family       | Plant species                  | Vernacular name | Plant extracts used          | Dose(s) used               | Models used in the study                  | Results                                                                 | References |
|--------------|--------------------------------|-----------------|------------------------------|----------------------------|-------------------------------------------|------------------------------------------------------------------------|------------|
| Solanaceae   | Solanum americanum Mill.       | Aneb dib        | Aqueous extract of the leaves| 200, 400 mg/kg BW          | Alloxan- induced diabetic rats            | Significant antihyperglycemic and hypolipidemic effects when compared to diabetic control rats \(p < 0.0001\)                              | [165]      |
| Theaceae     | Camellia sinensis (L.) Kuntze   | Attay           | Water extract                | 2 ml/100 g BW              | Streptozotocin-induced diabetic rats (STZ)| The inhibitory effect of extract on hyperglycemia induced by STZ was statistically significant                           | [166]      |
| Thymelaeaceae| Thymelaea hirsuta (L.) Endl.    | Metnan          | Aqueous extract of the aerial parts | 250 mg/kg BW              | Streptozotocin-induced diabetic rats (STZ)| In STZ-induced diabetic rats, single oral administration of T. hirsuta produced a significant decrease of blood glucose levels                                    | [167]      |
| Urticaceae   | Urtica dioica L.               | Taznaght/Tigzen/ Lhriga | Aqueous extract of the aerial parts | 500 mg/kg BW              | Alloxan- induced diabetic rats            | The amount of glucose absorbed in a segment jejunum in situ was 8.05 ±0.68 mg in presence of nettle extract vs. 11.11 ±0.75 mg in control rats during 2 h \(P < 0.05\) | [168]      |
| Urticaceae   | Urtica pilulifera L.           | Hurriga / Torokta/ Lhriga | Lectin isolated from the seeds | 100 mg/kg BW              | Streptozotocin-induced diabetic rats (STZ)| Significant hypoglycemic effect was found at the dose of 100 mg/kg after administration for 30 days                                         | [169]      |
| Vitaceae     | Vitis vinifera L.              | Dalya/Zbib/Kerma/ Adilite | Ethanolic extract of the leaves | 250 and 500 mg/kg BW       | Streptozotocin-induced diabetic rats (STZ)| The data show that 250 mg/kg of the V. vinifera extract has possessed remarkable effect on blood glucose level as equal as reference drug. (11.8-26.0%) | [170]      |
| Zingiberaceae| Zingiber officinal Roscoe      | Sekinjhir       | Aqueous extract of the root   | 500 mg/kg BW              | Streptozotocin-induced diabetic rats (STZ)| Raw ginger was significantly effective in lowering serum glucose, cholesterol and triacylglycerol levels in the ginger-treated diabetic rats compared with the control diabetic rats                                      | [171]      |
Plants used most frequently for the treatment of diabetes in Morocco

*Trigonella foenum-graecum* L.

*Trigonella foenum-graecum* L. (Fenugreek), is an annual plant, in the family Leguminosae, extensively cultivated in many countries (Morocco, Egypt, China, India, Ethiopia, Turkey, Ukraine, Greece, etc.) [172]. Apart from the usage as an edible species and spice herb, fenugreek is known for its nutraceutical, medicinal, and pharmaceutical features. It has been reported that fenugreek is a valuable medicinal plant with potential for curing abscesses, wounds, arthritis, bronchitis, digestive disorders, fever and sinusitis. It is cited as used in the treatment of diabetes by Moroccan ethnobotanical studies [2, 12–23]. Fenugreek is known to have several pharmacological effects such as antidiabetic, lactation aid, antibacterial, gastric stimulant, for anorexia, galactagogue, hepatoprotective effect, anticancer, anticarcinogenic, hypocholesterolemic, antioxidant, and immunological activities. Fenugreek is an excellent source of neutral detergent fiber, proteins, vitamins as well as chemical constituents [172–176].

Hypoglycaemic activity of alcoholic extract of seeds of *Trigonella foenum-graecum* was tested in both normal and alloxan-induced diabetic rats. Significant decrease in glycemia was seen with alcoholic extract (74.33 ± 4.77 to 60.56 ± 1.9 in normal rats and 201.25 ± 7.69 to 121.25 ± 6.25 in diabetic rats) (P < 0.001) [122].

Fenugreek water seed extract was found to increase the body weight and decrease the fasting blood glucose in streptozocin-induced diabetic rats [177]. Similar results were obtained in the study done by Abdelatif et al. [178] who found that there was a weight gain in fenugreek treated rabbits as compared to the group that received only alloxan monohydrate. Plasma glucose level was reduced as compared to the alloxan monohydrate induced diabetic rabbits.

Administration of *Trigonella foenum-graecum* seeds (2.5 and 5 g) for 4 weeks to sixty newly diagnosed diabetic patients, improved blood glucose level in dose-dependent. The medium dose (5 g) of fenugreek seeds reduces significantly the glycemia (8.83 vs 6.45, p < 0.05) [179].

An active compound (GII), isolated from water extract of seeds of fenugreek orally administered to the subdiabetic and mild diabetic rabbits, was capable of reduce blood glucose in glucose tolerance test [180].

*Artemisia herba-alba* Asso

*Artemisia herba-alba* Asso. (Compositae), known as the desert wormwood (Shih in arabic), is a dwarf, semi shrub, strongly aromatic herb, growing widely in arid and semiarid areas of the Mediterranean basin and in Western Asia spreading into middle east, north-western Himalayas and India [181, 182]. This species is used medicinally to treat various diseases such as hypertension, diarrhoea, diabetes, colds, muscle tensions, coughing, intestinal distress and fever [183, 184]. It is cited as used in the treatment of diabetes in Morocco [2, 12, 14–23].

Numerous scientists have showed various biological and pharmacological effects in *Artemisia herba-alba* essential oils, especially antibacterial, antispasmodic, anti-diabetic, antioxidant, leishmanicidal, and antifungal properties [185–188]. In essential oils, monoterpenes were the major components, essentially α- and β-thujones, camphor, 1,8-cineole and chrysanthenyl derivatives, but sesquiterpenes also were found in some countries [189–192].

Taştekin et al. [79] reported the hypoglycaemic effect of aqueous extract of *Artemisia herba-alba* in alloxan-induced diabetic rats. Aqueous extract of the aerial parts at the dose of 0.39 g/kg BW (body weight) significantly reduced (P < 0.05) blood glucose concentration. Its hypoglycaemic effect was comparable with that of insulin and repaglinide.

In vitro screening of hypoglycemic activity of *Artemisia herba-alba* using α-amylase inhibition technique emphasized its activity in hypoglycemic remedy. The 70% ethyl alcohol extract and mucilage of 70% ethyl alcohol inhibited the activity of α-amylase by 11% and 2% respectively [193].

A dose of 2 g/kg of hydro-alcoholic extracts of *Artemisia herba-alba*, orally administered daily for 18 weeks, to male mice fed high fat diet, significantly decreased the blood glucose level (143.8 ± 23.9 vs. 229.0 ± 20.8 mg/dl, p < 0.05), triglyceride (18.9 ± 11.1 vs. 62.8 ± 18.3 mg/dl, p < 0.05), total cholesterol (1.2 ± 0.1 vs. 1.8 ± 1.1 g/L, p < 0.05) and serum insulin concentrations (1.7 ± 0.7 vs. 3.3 ± 14.3 ng/ml, p < 0.05) [194].

*Nigella sativa* L.

*Nigella sativa* L. (Family Ranunculaceae), commonly known as black seed or Kalonji seed, is widely grown medicinal plant throughout the world. Seeds and their oil have many food and medicinal uses [195, 196]. It has received attention for its potential application in the treatment and prevention of a number of diseases, such as fever, asthma, diarrhoea, dyslipidaemia, common cold, headache, warts, stings of scorpions, bites of snake and rheumatic diseases [197–199]. Moreover, a variety of secondary metabolites has been identified in this species, such as fixed oil, protein, alkaloid, saponin, isochinoline alkaloids (nigellimine and nigellimine-N-oxide), pyrazol alcaloids (nigellidin and nigellicin), thymoquinone, p-cymene, pinene, dithymoquinone, thymohydroquinone, carvacrol, carvone, limonene, 4-terpineol and citronellol [195, 196]. It has been reported to possess potent anti-inflammatory, anti-hyperlipidemic, anti-microbial, anti-cancer, anti-oxidant, anti-diabetic, anti-hypertensive, hepatoprotective, antiparasitic, analgesic, anti-noiceptive, anti-ulcer, anti-histaminic and wound healing activities.
Nigella sativa used in Morocco in the treatment of diabetes [2, 13–23].

Alimohammadi et al. [146] reported the hypoglycaemic effect of hydroalcoholic extract of Nigella sativa seeds (5, 10, and 20 mg/kg BW) in streptozotocin-induced diabetic rats (STZ). Nigella sativa at 5 mg/kg reduced blood glucose concentration level from (565.4 ± 30.9 mg/dl) to (323.2 ± 32.2 mg/dl), at 10 mg/kg it reduced blood glucose concentration level from (565.4 ± 30.9 mg/dl) to (513.2 ± 42.7 mg/dl), whereas at 20 mg/kg it reduced it from (565.4 ± 30.9 mg/dl) to (517.6 ± 27.3 mg/dl).

The antidiabetic activity of methanolic crude extract and the commercial oil of Nigella sativa seeds in alloxan-induced diabetic rats was examined by Houcher et al. [201]. Administration of the crude methanolic extract at a dose of 810 mg/kg/day and the oil at a dose of 42.7 mg/dl, respectively [202].

Administration of the volatile oil extracted from Nigella sativa seeds experimentally caused a significant decrease in blood glucose level in alloxan-diabetic rabbits (565.4 ± 30.9 mg/dl) to (323.2 ± 32.2 mg/dl), at 10 mg/kg it reduced blood glucose concentration level from (565.4 ± 30.9 mg/dl) to (513.2 ± 42.7 mg/dl), whereas at 20 mg/kg it reduced it from (565.4 ± 30.9 mg/dl) to (517.6 ± 27.3 mg/dl).

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According to traditional medicine experts, Onion is one of the oldest medicinal plants used to relieve several ailments including metabolic disease, wound healer, pneumonia fighters, digestive problems, skin diseases and insect bites, diabetes and asthma [222, 223]. Allium cepa L., commonly known as onion, botanically classified under the Amaryllidaceae family, is a biennial plant widely cultivated around the world. Onion is utilized as both vegetable and flavouring [222, 223].

Allium cepa L.

Allium cepa L. (Olive) belongs to the plant family Oleaceae, is a small tree that produces the olive fruit, cultivated in the coastal areas of the eastern Mediterranean basin, the contiguous coastal areas of southeastern Europe, northern Iran at the south end of the Caspian Sea, western Asia, and northern Africa [203, 204]. Phytochemical investigations on Olea europaea have revealed the presence of various phytochemicals including phenolic compounds (oleuropein, hydroxytyrosol, verbascoside, apigenin-7-glucoside), flavonoids, secoiridoids, triterpenes, biophenols, benzoic acid derivatives, xylitol, sterols, isochromans and sugars [204, 205]. Olea europaea has a variety of medicinal properties and traditional uses. The plant has been used to treat diabetes, high blood pressure, cardiovascular diseases, influenza, chronic fatigue syndrome, to support time of recovery, immune system, stomach and intestinal diseases, common cold, malaria, dengue, severe diarrhoea, respiratory and urinary tract infections, and as mouth cleanser [204, 206]. Various biological activities of Olea europaea have been extensively studied like antihypertensive, analgesic, antimicrobial, anticancer, antihyperglycemic, antidiabetic, anticonvulsant, antioxidant, anti-inflammatory, immunomodulatory, antiviral, antinociceptive, and gastroprotective activities [203, 204]. It is cited in the ethnobotanical surveys that the plant is used in the treatment of diabetes in Morocco [2, 12, 13, 15–23].

Eidi et al. [137] showed the antidiabetic effect of alcohol extract of Olea europaea leaves in normal and streptozotocin-induced diabetic rats. Rats were divided into nine groups, group 1: normal control rats, groups 2, 3, 4: normal rats treated with Olea europaea, group 5: diabetic control rats, group 6, 7, 8: diabetic rats treated with Olea europaea, group 9: diabetic rats treated with glibenclamide. The administration of extract at a dose of 0.1, 0.25 and 0.5 g/kg BW for 14 days significantly decreased the blood glucose in diabetic rats (p < 0.05).

Another study was conducted to check the antidiabetic potential of oleanolic acid (an agonist for TGR5), isolated from Olea europaea leaves in mice fed with a high fat diet. Oleanolic acid cause a decrease in blood glucose concentration and insulin levels and it enhances glucose tolerance [207].

Several other studies demonstrated the antidiabetic effect of Olea europaea in streptozotocin diabetic rats [208–214], in alloxan diabetic rats [215–219], in alloxan diabetic rabbits [215], in human diabetic subjects [209] and in vitro α-amylase and α-glucosidase inhibitory activities [220, 221].
(292.3 ± 29.0 to 108.2 ± 4.6), at 250 mg/kg it reduced fasting blood glucose levels by 69.7 (296.3 ± 37.8 to 89.8 ± 4.3) whereas at 300 mg/kg it reduced it by 75.4% (297.8 ± 37.5 to 73.4 ± 3.0) [45].

Another study showed the hypoglycemic effect of onion juice on alloxan-induced diabetic rats. After 4 week treatment of onion juice (1 ml/100 g body weight), significant anti-hyperglycaemic effect were observed in treated rats [231].

The antidiabetic effect of 200 mg/kg body weight for 60 days of S-methyl cysteine sulfoxide (SMCS) isolated from Allium cepa was studied and compared in alloxan-induced diabetic rats. Results suggested that the administration of SMCS reduced blood glucose level [232].

In another experiment conducted by El-Soud and Khalil [233], they found that treatment with onion essential oil caused a significant decrease in serum lipids, lipid peroxide formation, blood glucose and increase in serum insulin in streptozotocin induced diabetic albino rats.

Marrubium vulgare L. Marrubium vulgare L. is a perennial herb of the Lamiales family, popularly known as white horehound. This aromatic plant is native to the Mediterranean Sea region can be found in many temperate regions of Europe, North of Africa and Asia [234, 235]. It could be used to cure and treat several diseases, such as laryngitis, bronchitis, skin abrasions, wounds, bronchial asthma, non-productive cough, hepatic affections and in phthisis [235, 236]. Marrubium vulgare is rich in phytochemicals like amino acids, polysaccharides, tannins, phenols, flavonoids, alkaloids, steroids, lactones and, in particular, terpenes [237, 238]. The plant is reported to possess hypoglycemic, vasorelaxant, analgesic, antioxidant, anti-erematogenic, anti-inflammatory, vasodilator and anti-hypertensive properties [236, 238]. Horehound used in Morocco in the treatment of diabetes [2, 12–19, 21–23].

Elberry et al. [102] showed that methanolic extract of the aerial parts of Marrubium vulgare can have beneficial effect in diabetes and its complication. They showed on a streptozotocin rat model the antidiabetic effect of a daily single oral dose of 500 mg/kg/day of Marrubium vulgare for 28 days. The methanolic extract produced a significant decrease in blood glucose starting on the second week and a significant increase in plasma insulin and tissue glycogen contents.

The administration of an aqueous extract from aerial parts infusion at dose 100, 200 and 300 mg/kg BW to alloxan-induced diabetic rats decreased significantly the blood glucose level in a dose dependent manner (a decrease by 50% for the dose 100 mg/kg and more than 60% for doses 200 and 300 mg/kg) [239].

The antidiabetic activity of various ethanolic extracts (root, leaf and stem) from Marrubium vulgare on normoglycemic rats was examined by Vergara-Galicia et al. [240]. The intragastric administration of both extracts (root and stem), at 100 mg/kg BW, significantly reduced blood glucose level in healthy rat. Furthermore, the increase in plasma glucose level was significantly suppressed by the ethanolic root extract after substrate oral administration.

Conclusion

Many Moroccan medicinal plants are reported to have blood sugar lowering properties that make them useful for the management of diabetes. We have reported 255 medicinal plants species belonging to 70 families in this study for the treatment of diabetes. Plants from the Compositae family were used most often in Morocco. The role of 135 Moroccan medicinal plants in the treatment of diabetes has been reviewed by several authors. However, 120 medicinal plants that are used for the treatment of diabetes in Morocco have not yet been studied in great detail for their antidiabetic properties. Furthermore, there are very few scientific reports of toxicological properties of these plants which would guarantee the safety of patients. In general, the literature search showed that some users of medicinal plants have only little information about toxic plants. In order to prevent the usage of toxic plants by the greater population, we have reported the major plants that have side effects according to toxicological documentations. Despite the therapeutic effects of medicinal plants they may have a toxicity risk which is related to a variety of causes including, contamination, misidentification, mistaken use of the wrong species, incorrect dosing and errors in use. Another problem, which may occur, is the possibility of adverse interaction between conventional medication and plant remedies. In conclusion, this review provides baseline data for plant species that have the potential antidiabetic activity and their associated knowledge in Morocco. However, many of the plant species mentioned require further pharmacological and clinical studies in order to validate any effective plant remedies to treat diabetes.

Abbreviations

BW: Body weight; DM: Diabetes mellitus; SMCS: S-methyl cysteine sulfoxide; STZ: Streptozotocin-induced diabetic rats

Acknowledgements

Not applicable.

Authors’ contributions

EI Manuscript preparation. FM Manuscript review. KC Supervising the whole work. All authors read and approved the final manuscript.

Funding

There is no funding for review article.

Availability of data and materials

Not applicable.
Ethics approval and consent to participate
Not applicable.

Consent for publication
Not applicable.

Competing interests
The authors declare that they have no competing interests.

Received: 26 October 2019 Accepted: 25 March 2020
Published online: 31 March 2020

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