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Parthvee Rupsinh Damor and A. C. Polaiah

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Research Review

Gymnema sylvestre as a Remarkable Sugar Balancing Medicinal Plant: A Comprehensive Review on Morphological, Biochemical and Biotechnological Interventions

Parthvee Rupsinh Damor*[1] and A. C. Polaiah[2]

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A B S T R A C T

Gymnema sylvestre, (Asclepiadaceae) is commonly known as madhunashini. It is distributed in major tropical and sub-tropical parts of the world. This medicinal plant is subjected to possess active constituent known as gymnemic acid which is responsible for the control of diabetes in humans. It is used for various other treatments also like asthma, eye complaints, inflammations, snake bites etc. *Gymnema sylvestre* is one of the most remarkable sugar balancing medicinal plants used mostly in curing diabetes in patients. It has various medicinal properties like antidiabetic, anticancer, antimicrobial, anti-inflammatory, radical scavenging, antiobesity and antiarthritic. Gymnemic acid is used with various formulations for the solution of obesity and urinary complaints. Micropropagation technique is used to increase the yield of Gymnema because of its poor seed germination and high economic value. The use of molecular markers is also significant for various biotechnological analysis in this medicinal plant. The present review highlights the medicinal and traditional uses, biotechnological interventions and pharmacological activities of Gymnema. According to various references and reviews it is advisable to use Gymnema in different forms to cure certain diseases and mostly for diabetes. The chemical composition includes secondary phytoconstituents. The main active constituent of *G. sylvestre* is gymnemic acids. There are various biotechnological interventions carried out by scientists which include various practices like micropropagation through *in vitro* and *in vivo* activity in gymnema, transcriptome analysis, plant tissue culture methods, use of molecular markers for the identification of genetic diversity. This technologies and findings in *Gymnema sylvestre* in biotechnology field has contributed to recent advances to increase the quality and yield of this medicinal crop.

***Key words*:** *Gymnema sylvestre*, Medicinal uses, Morphological, Molecular markers

Indian *Materia Medica* includes the uses of 2000 different types of drugs obtained from nature used by different traditional system and folklore practices. Gymnema is one such medicine used from ancient time. *Gymnema sylvestre* is a well-known medicinal plant species used for the treatment of diabeties from the ancient times. It is a woody climber belonging to the family Asclepiadaceae or milkweed family. It is mostly used in the traditional system of medicine. The taxonomic classification of gymnema showcases that it belongs to Kingdom Plantae with division Angiosperm and Class Dicotyledonae. It is said that the word Gymnema has been described from the Greek word 'gymnos'- 'naked' and 'nema'- 'thread' and the word sylvestre means 'of the forest' in Latin [1]. It is known as 'miracle fruit' though the main plant part used are leaves. One of the books of Ayurveda, i.e., Sushruta describes *Gymnema sylvestre* R Br protolouged Roem & Schult. Diabetes is a major health problem globally. According to the world health organization, around 80% of the population uses various plant parts for their primary health care. This disease is growing very fast and needs some interventions. *Gymnema sylvestre* is one of the medicinal plants used to cure diabetes. Gymnema is found generally in the tropical and subtropical regions of the world and thus the origin of the medicinal herb is tropical or sub-tropical Asia, South Africa, Oceania, China and Australia. Gymnema is also found in different parts of India. And in India, Gymnema is distributed in the forests of Central India, Western Ghats, Konkan, Tamil Nadu, Karnataka, Goa and Madhya Pradesh [2]. Gymnema is commonly known as Gurmar from ancient times. Gurmar means sugar killer because of its anti-diabetic properties. Diabetes mellitus is of the major and serious disease prevailing in the world. It is a disorder of carbohydrate, fat and protein metabolism which includes chronic hyperglycemia. Chewing of gudmar leaves reduces the sensitivity to the sweetness. It is also known to be popular in the western medicines [3]. The leaves and roots of gudmar are the most biologically active parts of Gymnema. The main active chemical constituent of Gymnema

* **Parthvee Rupsinh Damor**
✉ p.r.damor@gmail.com

[1] Children's University, Gandhinagar - 382 021, Gujarat

[2] ICAR-Directorate of Medicinal and Aromatic Plants Research, Boriavi - 387 310, Anand, Gujarat, India

is gymnemic acid. In India, Gymnema is identified with different names in different parts of the country. Accordingly, the vernacular names of *Gymnema sylvestre* are Gurmar (Hindi), Mardashingi (Gujarati), Kavali, Kalikadori, Vakundi (Marathi), Meshashringi, Medhunashini (Sanskrit), Adigam, Cherukurinja (Tamil), Podapatri (Telugu), Merasingi (Bengali) and Sannagerasehambu (Kanarese). The growth of gymnema is very slow against its demand in the market. To overcome, the demand in the market various approaches like in-vitro Micropropagation is carried out. The propogation of gymnema by seed germination is very difficult. Various factors affect the seed germination like drought, insect attack and poor ability of the roots to develop. This medicinal plant can be grown in all type of soils in tropical and sub-tropical regions at an altitude of 600m.

Based on the medicinal properties of gymnema, the extracts obtained from the plant are used in folk, Ayurvedic and homeopathic system of medicine [4]. Because of its active compounds it is used for pharmacological studies and ethnobotanical values. When the fresh leaves are chewed, the sense of taste of the sweet substance is paralyzed for some time [5]. Gymnema is used for mainly diabeties, weight loss, snake bite, antidote, digestive stimulant, laxative, appetite, suppressant and diuretic. The main use of gymnema is to control the level of sugar in the body. Also, there are various products, dietary supplements and health food available in the market based on gymnema in different parts of the country in Asia, America and Europe. It is observed that various phytochemicals such as resins, saponins, gymnemasine, sapogenin, anthraquinones, hentriacontane, pentatriacontane, phytin, tartaric acid, formic acid, butyric acid, gymnemic acid, gurmarin, gymnemasides, gymnemasins, stigmasterol, vitamins and flavonoids. Gymnemic acid A-D are the major secondary metabolites found in gymnema. Gymnema leaves extract contains monosaccharide and hence it is soluble in water and polar solvent. There is presence of carboxylic groups making it acidic in nature. There are various products available in the market obtained from gymnema like gymnema capsules, gymnema tea, bioshape and diaxinol which is used for the treatment of various diseases. Another various product like Body Slatto Tea, Gymnema, Gymnema Diet, Sugar Off, Glucoset™, Cinndrome X™ and Pilisoft™ are available in the market since last ten years [6].

Morphological characteristics of gymnema

Gymnema is a highly slow climbing vine and can reach upto the top of heighted trees. The chromosome number of gymnema is 2n=22. The stem of the plant is green with milky latex. The outer layer is waxy and hairy. The young branches are pubescent and glabrescent. Stem is cylindrical in shape and lenticellate. A leaf contains about 1cm long petiole, an oval elliptical leaf blade and pubescent on surfaces. Leaves are simple and opposite. Gymnema has transverse and reticulate venation [7]. Flowers are pedicellate and the pedicels are long. They are regular and pentamerous. It is polysepalous, gamopetalous, epipetalous, actinomorphic and zygomorphic [8]. The flowers are small and yellow while lateral umbel in cymes. The calyx is ovale and obtuse in shape. The petals are slightly light yellow in colour having a single corona and five fleshy scales. The scales are congenitally attached upto the corolla neck between the lobes. A membranous tip is formed from the anther connective. Two erect pollinia are observed. The locules are ovuled [9]. The main commercial varieties of gymnema are Jhalawar, Lotiajhir and RUBL 18050 (NKS 1343) [10. The flowering occurs in the month of April to November. The fruiting takes place in winters (December to March). The propagation of plant through seeds is difficult because the seeds are less viable. And hence the propagation is done through cuttings. The germination of plant is done using the mature seeds in small polybags during the month of October-December. Cultivation is also done using cuttings and further planting is done during rainy season.

Soil and climatic condition

It is observed that madhunashini grows well in two kinds of soils, red loamy soil or medium deep black soil. Also, this medicinal plant is susceptible to water logging conditions. Hence, water logging condition is avoided for the better growth of the plant. Madhunashini is found in tropical and sub-tropical agro-climatic conditions. It grows well in the area where rainfall is distributed high or medium.

Agronomic practices

Land preparation and fertilizer dose

The field is prepared by ploughing and turning the soil up and down. It is made free from the weeds. FYM is added to the soil which is in the quantity of 10 tonnes per hectare. The spacing for the plant is kept 1m × 1.5m. Crowbar method is used for planting the cuttings or seedlings [11].

Disease and pest control

It is observed that during the rainy season the apical tender parts of the plant are attacked by an aphid (*Aphis* sp.). The damage caused by the pest is not severe but regular control measures are required. The use of chemical pesticides is done very less because the leaves are to be harvested for the commercial purpose [11]. It is observed that thrips, mites and greenfly are the important insects of gymnema. It can be controlled by spraying Dimethoate (2ml/l). Mites can be controlled by Acaricide and greenfly by monocrotophos (1ml/l). Botanicals can also be used like extracts of garlic, Vitex negundo, Lantana camera, Clerodendron inerme and Calotropis gigantean. Another major disease in gymnema is powdery and leaf spot. It can be controlled by spraying 3g/l water soluble sulphur and 2g/l Mancozeb.

Crop harvesting

Harvesting of gymnema leaves can be done every three months. The leaves which are 30-40 days old are plucked for the use. For the better yield the harvesting is done after one year of the growth of the plant [11].

Storage

There is a still a lack of understanding the postharvest handling and packaging of the crop species. Medicinal plants which are freshly harvested are difficult to store and transport because of the maximum water content and risk of microbial degradation. According to a study by Padmapriya and Rajamani [12], the dried samples of gymnema can be stored in polythene lined gunny bags as it retained the alkaloid upto 4 months with 438.10 mg/100g of gymnemic acid.

Medicinal and traditional uses of Gymnema sylvestre

In India, there are different tribes and ethnic groups. The tribal groups are aware of their tradition, language and uses of medicinal plants available in their geographic area. Gymnema is one such medicinal crop found in the natural resources. Gymnema is one of the most important herbs used in the treatment of diabeties. It is bitter and astringent in taste. The major active components of *G. sylvestre* are a group of oleanane type triterpenoid saponins known as gymnemic acids [13]. It is often referred as ‘sugar destroyer’ as it paralyses the sweet

tasting buds and additionally lowers the blood sugar level. It is used for urinary disorders. It is also used as lipid lowering agent and weight loss. In Ayurvedic system of medicine it is used in hypo/hyperglycemic condition. It possesses antimicrobial, sweet suppressing and hepatoprotective activities. It is used for treating asthama, eye complaints, inflammation and snake bite [14]. Gymnema is used as a remedy for rheumatism, stomach pain and purifying of blood. The leaves of gymnema are used as antiviral, diuretic, antiallergic and dental caries. The juice of the roots are used to cure vomiting and dysentery. The whole plant paste mixed with milk is used for treating mouth ulcers [15]. The dry leaf powder is used in the treatment of bronchial asthama, cough, wounds and leprosy [16-17]. The gymnema bark is used in the treatment of phlegm and the roots are useful for the ailment of piles [18]. Gymnema acts as an anti-cancer and cytotoxic agent. It helps in lowering the serum cholesterol. The water retention and liver related diseases can be decreased by using gymnema. The tribe residing Nagari Hills, north Arcot district, near Bombay and Gujarat have the habit of chewing fresh green leaves of gymnema in the early morning to keep their urine clean. Rajasthan people use this plant for their gastric troubles. While in Andhra Pradesh it is used to treat glucosuria.

It is a bitter, cardiotonic, anti-arthritic, alexipharmic, expectorant, acrid and stimulant. It is used as cytotoxic agent and in the treatment of cancer. It is useful in amennorhoea, bronchitis, cardiopathy, conjunctivitis, antidysentery and cough. It is also used to cure intermittent fever, laxative, constipation, jaundice and inflammation. It is used for the treatment of hyper cholesterolemia and leucoderma. It is used as anti-inflammatory and smooth muscle relaxant, obesity and weight loss.

Chemical composition of Gymnema sylvestre

The medicinal value of the plant is identified with the presence of secondary phytoconstituents which have definite physiological role in the human body. Phytochemicals are the bioactive chemicals of the plant and they are regarded as secondary metabolities. Secondary metabolities are naturally synthesized in all the parts of the plant body. The main active constituent of G. sylvestre is gymnemic acids. The leaves of *G. sylvestre* contains triterpene saponins, resins, albumin, chlorophyll, carbohydrates, tartaric acid, formic acid, butyric acid, anthraquinone derivatives, inositole alkaloids, organic acid (5.5%), parabin, calcium oxalate (7.3%), lignin (4.8%), cellulose (22%). The *G. sylvestre* contains triterpene saponins which belong to the classes oleanane and dammarene. Oleanane saponins class contains gymnemic acids and gymnemasaponins while dammarene saponins class contains gymnemasides. In Gymnema extracts, groups of anti-sweet principles with a novel D-glucoside structure i.e., Gymnema saponins I-V is present. The plant constituents like flavones, anthraquinones, hentri acontane, pentaria contane, phytin, d-quercitol; β- amyrin related glycosides and stigma sterol are present. A polypeptide comprising of 35 amino-acid residues known as gurmarin which is an anti-sweet agent is also found in Gymnema [19]. *Gymnema sylvestre* not only contains gymnemagenin but also 23-hydroxylongispinogenin, gymnestrogenine and few of the dammarane derivatives. 3-O-glucuronide of gymnemagenin is obtained from the latter which contains several acylated derivatives of deacylgymnemic acid [20]. The major secondary metabolites found in gymnema are a group of nine closely related acidic glycosides i.e., gymnemic acid A-D and it is found in all parts of the plant.

Gymnemic acid is found in every part of the *Gymnema* plant in different quantity. In one of the studies, it is reported that gymnemic acid content is maximum in shoot tips (54.29 mg/g DW) followed by the gymnemic acid content in leaves, flowers, nodes, internodes and roots i.e., 27.67, 31.66, 28.81, 25.39 and 20.56 mg/g DW) while the minimum amount of accumulation of gymnemic acid was observed in seeds [21]. Gymnemic acid (gymnemagenin and saponins) stimulates the release of endogenous insulin and blocks the glucose receptors which lower the blood sugars. Gymnemic acid individually includes gymnemic acid I-VII, gymnemasides A-F, gymnemasaponins. It is reported that (+) quercitol, lupeol, (-) amyrin and stigma sterol are found in Gymnema. A new flavonol glycoside i.e., kaempferol 3-O-beta-D-glucopyranosyl-(1→4) - alpha-L-rhamnopyranosyl-(1→6)-beta-D-galactopyranoside has been found in aerial parts of *G. sylvestre*.

Gymnemic acids VIII-XII are identified as glucosideuronic acid derivatives of gymnemagenin [22]. Gymnemic acid mainly acts at the receptor location in the absorptive layer of intestine and hence prevents the absorption of sugar molecules by the intestine which lowers the blood sugar level [23]. Gymnemic acid blocks the sugar absorption in and stimulates the β-cells of pancreas and rejuvenates it. Gymnemic acid increases secretion of insulin and promotes the regeneration of islet cells [24]. There are various phytochemicals present in this herb. Each phytochemical has different pharmacological activity. Ascorbic acid acts as acidulant, antiaging, antidote, antiinflammatory, antiparkinsonian, antiseptic, antipoptotic and vulnerary. Beta-carotene acts as antiacne, antilupus, antidyskinetic, interferon-synergist, phagocytotic and thymoprotective. The phytochemical present in gymnema known as conduritol-A acts as aldose-reductase inhibitor, gastro-stimulant, ribosome-inactivator, cyclo-oxygenase inhibitor, molluscicide and serotoninergic [25]. *Gymnema sylvestre* is rich in alkaloids, flavonoids, tannins and saponins which show medicinal and physiological activities. Gurmarin an important 35- amino-acid peptide is also present in *gymnema sylvestre*.

Biotechnological aspects in Gymnema sylvestre

The biotechnological aspects include various practices like micropropagation through *in vitro* and *in vivo* activity in gymnema, transcriptome analysis, plant tissue culture methods, use of molecular markers for the identification of genetic diversity.

Micropropagation studies in Gymnema

Micropropagation technique is required on a commercial base in gymnema to cope up with the market demand and save the species from extinction. It is studied that methods like micropropagation and callus induction is carried out to enhance the production of phytochemicals in gymnema. In vitro propagation is the best method to increase the rate of large-scale multiplication, improvement and conservation of the plant. Hence to meet the requirement of commercial market micropropagation is necessary. The first report of in vitro callus induction and plantlet regeneration in *G. sylvestre* was reported without any visually phenotypic variations [26]. Hardening and acclimatization is carried out when the plantlets have attained a height of 8-10cm and further they are transplanted in small plastic trays containing sand: soil (1:1). In an experiment of in vitro multiplication of *G. sylvestre* R. Br. through nodal explants it was observed that among the different combinations used the MS medium treated with BA at 1.0 mg/l was found favourable for induction of multiple shoots [27]. In a study of in vitro propagation four steps were involved i.e., culture establishment, shoot multiplication rooting and hardening. Five nutrient media MS (Murashige and Skoog), WPM (Woody

Plant Medium), B5 (Gamborg medium), SH (Schenk and Hildebrandt medium) and NN (Nitsch and Nitsch medium) and five sources of cytokinins i.e., (Ads (Adenine hemisulphate), BA, Kinetin, 2-iP (N6-(2-isopentyl) adenine and TDZ (Thidiazuron) were used using six different combinations of concentration of cytokinins (0, 1.25, 2.5, 5.0, 10.0 and 20.0 µM). It was observed that in all possible interactions in two successive experiments, NN (Nitsch and Nitsch medium) and 5.0 µM BA significantly proved better for the in vitro shoot multiplication in gymnema [28].

Molecular markers in gymnema

Molecular markers-based selection is the most promptly used method for selecting the traits. A genetic marker is associated with a particular trait. It is a gene or sequence with specific place on chromosome. It is used to identify the percentage of polymorphism in different genotypes of plant. In an experiment carried out by Verma *et al.* [29] in *G. sylvestre*, 40 ISSR primers were screened. Among 40 screened primers, 15 were found polymorphic. These ISSR markers used were highly polymorphic and hence it can be utilized as molecular probes for further selecting high yielding genotypes. Twenty-four different gymnema accessions were studied using RAPD markers. It was observed that 74% genetic similarity was recorded among the accession collected from different regions [30]. An investigation was carried out on twelve selected progenies of gymnema through AFLP markers using 64 primer combinations. It was observed that different primer combinations detected different level of polymorphism ranging from 33% to 69.8% [31]. Molecular differences of seven population of gymnema were investigated using RAPD markers. For the analysis, thirteen primers were used revealing 112 bands out of which 62 were polymorphic [32].

Pharmacological activity of Gymnema sylvestre

The pharmacological activities include antidiabetic activity, anticancer activity, antimicrobial, lipid lowering, antioxidant, antiobesity, antiarthritic, anti-inflammatory, immunomodulating, anticaries and hepatoprotective activity.

Antidiabetic activity of Gymnema sylvestre

It was observed that the ethanol extract of plant reduce glucose level by 46% while water and methanol extract reduced glucose level by 26% and 12% respectively. As examined in a diabetic animal model, *gymnema sylvestre* reduced the blood levels of insulin, protein, triglycerides, cholesterol and glucose. It was also found to reduce live histopathology [33]. An experiment was undertaken and the hypoglycemic effect of G. sylvestre on beryllium nitrate and streptozotocin treated rats [34]. The effect of *gymnema sylvestre* extract on normal and alloxan induced diabetic rats was studied. A dosage of 400, 600 and 800mg/kg body weight was administered orally once a day continuously for 30 days. In an experiment, patients with type-II diabetes were treated with Gymnema leaf extract with a dosage of 400 mg/day for 18-20 months. It was observed that it helped to regenerate β-cells and raised insulin level in serum of the patients [35].

Anticancer activity

It is reported that saponins which are derived from the plants like ginsensosides, soyasaponins and saikosaponins have significant anticancer activities. A plant constituent named gymnemagenol ($C_{30}H_{50}O_4$) obtained from gymnema showed positive anticancer activity against HeLa cells which are responsible for cancer [36]. Gymnemagenol obtained from gymnema with different concentration was incubated for two different time lapses i.e., 48hrs and 96hrs. It was observed that gymnemagenol with the concentration of 50µg/ml showed good cytotoxic activity on HeLa cells responsible for the cancer [37]. Arunachalam *et al.* [38] 2015 studied the potential anticancer properties of bioactive compounds of *Gymnema sylvestre* and its biofunctionalized silver nanoparticles. It was resulted that *In vitro* cytotoxicity activity of biofunctionalized silver nanoparticles were used against the sensitivity of HT29 human colon adenocarcinoma cells is higher than Vero cell line for the same cytotoxic drugs responsible for HT29. It was also higher than the bioactive compound of the aqueous extract.

Radical scavenging activity

Gymnema sylvestre showed DPPH, superoxide, hydrogen peroxide and hydroxyl scavenging activity. The DPPH radical scavenging activity was observed most powerful in *gymnema sylvestre*. The values of radical scavenging activity ranged from 27.119 to 77.966% at the concentration from 10-500µg/ml and the standards ranged from 71.186 to 94.915%. For the hydroxyl radical activity, the extract obtained from methanol and ascorbic acid was compared and it was observed that ascorbic acid plant extract had better radical scavenging activity. The same was observed for superoxide radical scavenging activity [39].

Antimicrobial activity

The antimicrobial activity against various pathogens was studied. Various pathogens like *S. aureus*, *E. coli* and *B. subtilis* showed the antimicrobial activity when studied while gram negative bacteria showed no activity. The antibacterial activity of *gymnema sylvestre* and gymnemic acid was studied against *E. coli* and *B. subtilis* and it was observed that the antimicrobial activity was significant against the microbes [40]. From the various studies it was observed that the methanolic and ethanolic leaf extracts of *gymnema sylvestre* had antibiotic and antimicrobial activity. The antimicrobial activity of *G. sylvestre* extract i.e., aqueous, methanol, chloroform and hexane were studied against the microbes like *Staphylococcus aureus*, *Bacillus cereus*, *Klebsiella pneumonia*, *Escherichia coli*, *Candida albicans*, *Candida tropicalis*, *Candida krusei and Candida kefyr*. Various methods like agar well diffusion method, minimum inhibitory concentration, minimum bactericidal concentration and minimum fungicidal concentration were carried out. It was observed that methanol leaf extract of *G. sylvestre* showed significant antimicrobial activity against *E. coli*, *B. cereus*, *C. albicans* and *C. kefyr* [41].

Antinflammatory activity

The phytoconstituents of *Gymnema sylvestre* like tannins and saponins showed the anti-inflammatory activity. It was observed that methanolic extract of gymnema showed anti-inflammatory activity in Wistar rats in which rats were introduced with carrageenan inflammation [42]. In a study, in vivo two-staged carcinogenesis was introduced in mice using 7, 12-dimethylbenz[a] anthracene as an initiator and 12-O-tetradecanoyl phorbol-13-acetate as a promoter. Ethanolic extract of gymnema reported to show inhibitory effect against TPA-induced inflammation with a 50% inhibitory dose of 50-555 nmol/ear [43].

Antiobesity activity

Gymnema sylvestre is said to reduce the weight of a person as it has ability to reduce cravings for sweet taste and it possibly help reduce sugar levels. In a study it is reported that gurmarin peptide block the ability to taste sweet and thus reduce the sugar cravings. A study was conducted in which a

standardized *G. sylvestre* extract was combined with niacin bound chromium and hydroxycitric acid for evaluating the anti-obesity activity. It was observed that there were changes in body weight, body mass index, appetite, lipid profiles, serum leptin and excretion of urinary fat metabolites. Thus, it can be concluded that antiobesity activity was observed.

Antiarthritic activity

It was observed that the petroleum and aqueous extract of gymnema possessed the antiarthritic activity. A study was carried out by inducing arthritis in rats. It was resulted that petroleum ether extract and aqueous of Gymnema possessed anti-arthritic activity of gymnema [44]. Gymnema extracts were evaluated from aqueous and ether extracts for its antiarthritic activity in Freund's adjuvant induced arthritic rat. It was observed to be effective because it is a rich source of saponins, triterpenoids and steroids [45].

Green synthesis of nanoparticles by gymnema extract

Green synthesis of nanoparticles minimizes the generated waste and implements the sustainable processes. Nanoparticles are used in the field of Medicine and Pharmacy. The use of plant extracts in the synthesis of metal nanoparticles is studied by various researchers. The Gymnema extracts are eco-friendly, stable and have faster rate of synthesis [46]. The medicinal properties of bioactive compounds were increased by biofuntionalizing the gold nanoparticles and it was suggested that it can be used as anticancer drug [16]. The gold nanoparticles obtained from extracts of Gymnema are stable, non-toxic and economic [47] studied the green synthesis of silver and gold nanoparticles from *gymnema sylvestre* leaf extract and resulted that the phytoconstituents in Gymnema leaf extracts caused biological reduction of $AgNO_3$ and $HAuCl_4$ and produced silver and gold nanoparticles. It was observed that this biosynthesis showed in vitro antioxidant activity and also cytotoxic effects against Hep2 cells responsible for cancer. The green synthesis of silver nanoparticles synthesized from G. *sylvestre* is economical and nontoxic and it showed the antimicrobial and antioxidant activity [48].

CONCLUSION

In the review paper, the main aim was to present the overall summary of a medicinal plant, i.e., *Gymnema sylvestre* which is used to reduce *Diabetes mellitus.* The information regarding the morphological review and the agronomic practices helps to increase the sustainable yield of the crop. The molecular studies describe the genetic diversity among different species of Gymnema. The studies of various pharmacological activities show the anticancer, antidiabetic, antiobesity and antiarthritic properties of *Gymnema sylvestre*. Therefore, it seems that use of this medicinal plant as therapeutics will improve the management of sugar level in diabetic patients.

Declaration

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Authors' contributions

I Dr. Parthvee Rupsinh Damor have analyzed all the review and research papers related to the above cited subject 'Gymnema sylvestre as a remarkable sugar balancing medicinal plant: A comprehensive review on morphological, biochemical and biotechnological interventions.' and contributed in writing this manuscript.

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