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Review Article

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A Critical review on *Salvadora persica*: An important medicinal plant of arid zone

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Abstract

S. persica is a multipurpose tree with immense ethno-ecological importance and is commonly used for varied medicinal purposes. It is one of the identified plants from among the seventeen plants families that are cited in the Holy Quran. The plant is used as a source of food, fodder, lipids, gum and resins. In addition, it is also valued for rearing honey bees. Its roots are regularly used as tooth brush throughout the country. Besides these the plant is also grown to provide shelter-belts and windbreakes for agriculture crops. It is distributed throughout the arid and semi-arid ecosystem of world and helps in reclamation of sand dune habitats and saline soils in arid ecosystems. However, its population suffers from serious environmental problems such as deforestation, soil degradation, loss of biodiversity and unsustainable livelihoods. *S. persica* has high medicinal, economic and ecological values in arid and semiarid ecosystem. Nevertheless, its conservation status is highly threatened and detailed ecological study of *S. persica* is suggested to conserve its remaining population.

Keywords: Biological activity, Micropropagation, Miswak, Salvadora persica

Introduction

The genus *Salvadora* belongs to family 'salvadoraeceae'. It comprises three genera (i.e. *Azima*, *Dobera* and *Salvadora*) and 10 species distributed mainly in the tropical and subtropical region of Africa and Asia [1]. In Indian subcontinent this family is represented by only one genus with two species viz. *S. persica* and *S. oleoides* [2-4]. Recently, a new species *Salvadora alii* has been described from Sindh, Pakistan [5]. *S. persica* is a popular chewing stick commonly known as 'miswak' and is one of the most popular medicinal plants throughout the Indian subcontinent, as well as the wider Muslim world [6-11]. *Salvadora persica* has antiurolithiatic properties. It is used for centuries as a natural toothbrush; its fibrous branches have been promoted by the World Health Organization for oral hygiene. The plant has been used for the preparation of a number of medicinally important products such as abrasives, antiseptics, astringent, detergents, enzyme inhibitors and fluorides [12].

S. persica (Miswak) is used traditionally in the treatment of rheumatism, leprosy, gonorrhoea, ulcers, scurvy, tumours and dental diseases [13,14]. It possesses a number of potential medicinal compounds viz. Salvadoricine, salvadourea, trimethyl amine, β-sotisterol, di-benzyl thiourea, rutin, thioglucoside, chlorine, potash, sulphur etc [15,16]. Besides its medicinal potentialities, it is also suitable in agroforestry systems as a wind break and helps in land reclamation [17,18]. The ripe fruits of this tree are sweet and edible (locally called as Piloo) and consumed by rural/tribal population. The seeds of *Salvadora* yield a pale yellow solid fat, rich in lauric and myristic acid content which is used in making soaps, illuminants, varnishes, paints as well as in food industry. It is recognized as nonconventional oil seed tree crop.

The tree coppices fairly well and branches are cut repeatedly to produce short stems that are harvested for toothbrushes [19]. It regenerates freely by root suckers and natural layering. It is, although very slow growing, however, a dense growth is often formed around the parent plant by root suckers and some natural seedlings. The plant provides a dense shade. It is often lopped for camel and goat fodder.

It is grown in plantations or hedges. The seed has high genetic variability [20], mainly because; its cultivation is restricted to dry and saline areas of some countries. Cultivated seedlings and trees must be protected from browsing by animals [21].

The taxonomic position of *Salvadora persica* is as follows:

Binomial name:	*Salvadora persica*
Kingdom:	Plantae
Division:	Magnoliophyta
Class:	Magnoliopsida
Order:	Brassicales
Family:	Salvadoraceae
Genus:	*Salvadora*
Species:	*persica*

The plant is named in different languages as below:

English:	Salt Bush tree, Tooth Brush tree
Hindi:	Pilu, Jhak, meswak

Malayalam:	Uka, Ukamaram
Unani:	Miswaak, Araak.
Marathi:	Khakan, Pilu
Tamil:	Uka
Telugu:	Gunnangi
Kannada:	Gonimara
Sanskrit:	Gudaphala, Lakhupeelu, Pilukaa

Botanical description

S. persica is a slow growing, evergreen perennial halophyte capable of growing under extreme conditions, from very dry environments to highly saline soils [22]. It is a shrub or a small tree which grows up to 10 meters in height and a girth of 3 feet. Main trunk is erect or trailing, more than one foot in diameter, with profusely branched, wide crown of crooked, straggling and drooping branches. Young branches are green in colour. Bark is slightly rough, grayish brown on main stem, paler elsewhere. Leaves are opposite, entire, succulent, petiolated, fleshy, oblong elliptic to almost circular, 3x7cm, light to dark green, with 5-6 pairs of main nerves. New leaves are produced during April, which on maturity become thick and leathery. Leaves shed from late December to January. Flowers are small, greenish yellow in axillary and terminal panicles, sessile or sub-sessile, bisexual and tetramerous. Small greenish-white flowers are produced in January to April. The fruit is yellow and ripens in the months of May and June. Mature fruits are spherical or globose drupe with persistent calyx, smooth, fleshy, 5-10 mm in diameter, pink to scarlet and single seeded. Seeds turn from pink to purple-red and are semi-transparent when mature [23,24]. Seeds are dispersed by birds, animals and man after they eat the fruit. Furthermore, *S.* species are deep rooted mesomorphic xerophytes as well as facultative halophytes with high salt tolerance [3, 25-27].

Ecology and distribution

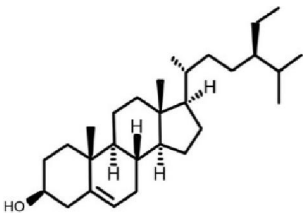
S. persica is an evergreen tree found at an altitude of 1800 meters. It is widespread in arid regions, on saline lands and in coastal regions, thorn shrubs, desert flood plains, and grassy savannahs [28,29]. It prefers areas such as riverbanks, on perimeters of waterholes, along drainage lines in arid zones and in seasonally wet sites where ground water level is high indicating its tolerance to a wide range of water, soil and soil pH conditions and that is probably the main reason for its widespread nativity [30,31]. The plant is also found in valleys, on dunes and on termite mounds. Annual rainfall requirement is 300-1000 mm. The tree is able to tolerate a very dry environment with mean annual rainfall of less than 200 mm. It prefers clays but also found on loam, black soils and sand. It is adapted to alkaline or very saline soils, usually clay-rich, and soils without salt.

S. persica showed some variations in its distributional behaviour in different countries, which may be attributed to changes in water resources, climatic factors, edaphic variables and anthropogenic pressures along the elevation gradient [32]. It is native to Algeria, Egypt, India, Nigeria, Pakistan, Saudi Arabia, Sri Lanka, Uganda and Zimbabwe. In India it is distributed in arid and semi-arid regions of Rajasthan, Gujarat, to some extent in Punjab, Haryana, Karnataka, Andhra Pradesh and Tamil Nadu [29].

Phytochemistry

S. persica is known to contain several biologically active chemical constituents such as volatile oils, flavonoids, alkaloids, steroids, terpenoids, saponins, and carbohydrates [33-35]. Almost every part of the plant has pharmaceutically important ingredients. The leaves, roots and stem bark contain an alkaloid trimetylamine. The seed is rich in oil and contains lauric, myristic and palmitic acids. Its oil has high potential for making soaps, candles and to be used as a substitute for coconut oil [19]. The root contains elemental gammamonoclinic sulphur, benzyl glucosinolate, salvadourea (a urea derivative), m-anisic acid and sitosterol [36]. Benzyl isothiocyanate which is isolated from the root, exhibits antiviral activity against Herpes simplex virus-1 which affects oral region.

According to chemical and phytochemical analysis of *S. persica*, its stem yielded octacosanol, 1-triacantanol, β-sitosterol, and β-sitosterol-3-O-β-d-glucopyranoside [37]. On examination by thin layer chromatography, it was found to be a mixture of 2 compounds, which were separated by column chromatography. The first compound (Compound A) had a melting point 136-138ºC, *m/z* = 414 (mass) and molecular formula $C_{29}H_{50}O$. It gave positive Salkowski, Liebermann, Burchard reaction, Noller reaction, Brieskron, Tschagajew, and yellow color with tetranitro methane [38-40]. Peaks in the infrared spectrum at V_{max}^{KBr} 3500, 1450, 1470, and 1145cm^{-1} showed its identity as compound β-sitosterol in white needle form (Figure 1). The second compound (Compound B) was found to be the white crystalline compound, with the molecular formula $C_{35}H_{60}O_6$, m.p. 265-268ºC, gave positive test for saponin and on hydrolysis yielded β-sitosterol and sugar glucose and hence identified as β-sitosterol-3-O-β-d-glucopyransoside. Essential oil contained α and β-thujones, camphor, cineole, β-cymene, limonene, β-myrcene, borneol, linalool, and bornyl acetate and nonvolatile fraction contained humulene, caryophyllene, β-santatol, and farnesol [41].



Structure of β-sitosterol

Benzylamide were also isolated. The isolated compounds were identified as butanediamide, N1, N4-bis (phenylmethyl)-2(S)-hydroxy-butanediamine (1), *N*-benzyl-benzamide (2), *N*-benzyl-2-phenylacetamide (3), and benzyl urea (4). *N*-benzyl-2-phenylacetamide revealed a significant inhibitory effect on human collagen-induced platelet aggregation, and a moderate antibacterial activity against *Escherichia coli* [42,43].

Propagation and management

S. persica germinates readily from seeds and also coppices well. Seeds exhibit no dormancy but the fruit pulp contains germination inhibitors that should be removed before sowing. The process of seed germination starts with imbibition in water at 30-35ºC for 24-72 hours, but under saline conditions the absorption of water is dependent upon osmotic pressure of the media and cell sap. Soaked, depulped seeds of *S. persica* germinate in 24 hours. Seeds are raised in the nursery for up to 3 years prior to transplanting in the field [44].

Seed viability is only about 30 percent [12,45,46] as oil-rich seeds of *S. persica* cannot be stored for longer periods. Besides, the seeds are infested with insects and pathogens. Since *S. persica* is a cross-pollinated species, the seeds do not produce true to the mother plant. Clonal fidelity of plants selected for particular character cannot be maintained if propagated through seed as segregation of characters occurs in seed-raised progenies. Seed-raised plants exhibit wide variations in (i) plant type and size (ii) colour, taste, size and sugar content of fruits, and (iii) seed oil content.

Achievements in S. persica through tissue culture

Micropropagation refers to *in vitro* propagation of plants in an aseptic, controlled and artificial environment which includes axillary budding, induction of adventitious buds and somatic embryogenesis. This technique in fact is the outcome of work of Haberlandt (1902) [47] and is a better alternative to the conventional method of vegetative propagation for raising of elite species, with conservation of space and time [48,49]. This technique offers a rapid means of multiplying woody biomass, and conservation of elite and rare germ plasm [50-52]. The efficient regeneration of plants from cell, tissue, and organ culture is recognized as prerequisite for application of modern genetic and biotechnological approaches to crop improvement [53-54]. Several workers have recognized that the two patterns of *in vitro* differentiation i.e organogenesis and somatic embryogenesis are distinctly different process [53-55] and several reports have been published on regeneration of *S. persica* through organogenesis in recent years (Table 3).

Tissue culture as a method of propagation of *S. persica* was reported using juvenile cotyledonary node [12]. Cotyledonary nodes excised from 15-20 days old seedlings germinated *in vitro* served as explant. Cotyledonary nodes were cultured on MS medium supplemented with different concentrations of cytokinins and auxins. Maximum shoot proliferation from single explant was obtained on MS medium incorporated with BAP (4.0 mgl^{-1}), IAA (0.5 mgl^{-1}), adenine sulphate (40 mgl^{-1}), glutamine (100 mgl^{-1}) and thiamine HCl (10 mgl^{-1}). *In vitro* produced shoots were induced to root on half strength MS medium supplemented with a range of IBA concentrations (0.5-5.0 mgl^{-1}). The highest frequency of root proliferation was on half strength MS medium supplemented with 3.0 mgl^{-1} IBA. The regenerates were transferred to field conditions after acclimatization with a success rate of 60 %.

A rapid clonal propagation system has been developed for *S. persica* through apical meristem [45]. The explants were taken from two-year-old plants. Shoot tips were inoculated on MS medium fortified with 4.0 mgl^{-1} BAP + 4.0 mgl^{-1} Kn along with activated charcoal (0.3 %). The shoot tips grew fast within 7 days alongwith well developed roots on the same medium. Thus complete regeneration of *S. persica* plants could be achieved in a single step.

Nodal segments of fresh shoot sprouts originated from axillary buds obtained from a mature tree (around 35-40 years old) have also been used as explants for establishment of *in vitro* cultures [56]. Surface-sterilized explants produced optimum number of shoots through activation of axillary buds on Murashige and Skoog's (MS) medium containing 2.0 mgl^{-1} BAP, additives (25 mgl^{-1} each of adenine sulphate, arginine, citric acid and 50 mgl^{-1} ascorbic acid). The shoot multiplication has been observed to be influenced by the successive transfer of the mother explants for 4-5 passages. The maximum numbers of shoots have been obtained on MS supplemented with 0.25 mgl^{-1} BAP + 0.25 mgl^{-1} Kn + 0.1 mgl^{-1} NAA. About 90 % shoots pulse-treated with a combination of 500 mgl^{-1} IBA + 100 mgl^{-1} NOA (2-naphthoxy acetic acid) were rooted *ex vitro* on soil rite within 15-18 days [56]. Over 80 % cloned plantlets were hardened successfully in a green house.

Tree management

For high seed settings and seed oil content, harvesting is recommended 3 months after seed setting. This may be due to the utilization of food reserve in the cotyledons for the development of fruit pulp.

Germplasm management

There are about 3400 seeds/kg. Its seeds are orthodox; therefore seeds may be stored with low moisture content.

Functional uses

Food: Fruits have a sweet, aromatic, slightly pungent and peppery taste. They can be eaten raw, cooked, or dried and stored. Fruit with or without seeds is said to contain 1.7-1.8 % sugars when ripe. Fermented drinks are also made from the fruit. The leaf is somewhat bitter and aromatic, with mustard like taste. The leaves are also cooked as a sauce and eaten as a green vegetable. Tender shoots, seeds and seed oil are also edible. Edible salts are obtained from ashes.

Fodder: Leaves and young shoots are browsed by all kinds of livestock, but normally cattle do not occur in the driest part of the *S. persica* distribution range and hence it tends to be valued more as a camel, sheep and goat forage. Leaves are fleshy and make good fodder as their water content is high (15-36 %) and are rich in minerals [44]. The high salt content of the leaves is said to affect the taste of milk, but the leaves are said to increase lactation in cows.

Toothbrushes: Young stems of 3-5 mm are used as toothbrushes. A toothstick is also said to relieve toothache and gum disease, and

the leaves are used as a mouthwash and for tooth and gum problems. The bark is said to contain an antibiotic which suppress growth of bacteria and the formation of plaque in the mouth [57].

Apiculture: *S. persica* is reported as a good source of nectar.

Fuel: The wood is sometimes used for firewood and charcoal. However, it is not used for cooking meat, as it leaves a foul taste.

Timber: The wood is soft, white, and easy to work and is not liable to termite attack. It is used for coffins and clubs.

Gum or resin: Resin that drips from the tree is useful for making varnish.

Lipids: Seeds of *S. persica* contain 30-40 % of greenish-yellow, non-edible oil that has over 50 % lauric and myristic acids. It has a high melting point and a disagreeable odour that disappears on purification. The most important aspect of the oil is the presence of a low percentage of C8 and C10 fatty acids that are of great economic significance. The oil is an alternative source of oil for soap and detergent industries.

Medicine: *S. persica* is harvested as wild rather than cultivated and about 80 % world population use it as natural remedy for the treatment of different diseases such as asthma, bronchitis, cough, scurvy, constipation, worm infestation, hemorrhoid and poisons [6,58-60]. Plant has anti-inflammatory, hypoglycaemic, and antibacterial properties. The fruit are aphrodisiac, carminative, and emollient, purgative and cures urinary and biliary calculi and arthritis. Leaf decoction is used for cough and asthma, poultice is used in painful piles and tumours; and juice is used in scurvy. Flowers are stimulant, laxative, and applied in painful rheumatic conditions. They are useful in gastric problems, constipation, oligospermia and sexual weakness. Tender twigs are used as toothbrush. Seeds are used as a tonic, diuretic, purgative and seed oil applied locally on rheumatic swellings and in chronic arthritis. A decoction of the root is used to treat gonorrhoea, general body pain, back pain, spleen trouble, chest congestion and stomach-aches. The roots are prepared as a salve and rubbed on the face for headaches. Roots are also used for chest diseases or pounded and used as a poultice to heal boils. The bark is scratched and the latex used for treating sores.

Other products: Crusted leaves placed in cow urine together with leaves of *Pergularia tomentosa* are used to clear hair from tanned hides, allowing the hair to be removed with a knife. Roots contain salvadourea, a urea derivative.

Services: Besides medicinal claims, *Salvadora persica* is planted as shelter belts and serve as windbreaker to protect farm habitation, gardens and orchards and a source of dune sand reclamation as well as saline soils reclamation [61-66].

Pests and diseases

When *S. persica* occurs on river terraces, it is a preferred host of *Cistanche tubulosa*, an obligate phanerogamic root parasite. Defoliating larvae of several beetles attack the tree, and leaves are often attacked by the *Lepidopteran colotisephiae*. The mite *Eriophyes* causes leaf gall. A number of fungi such as *Cercospora udaipurensis, Placosoma salvadorae* and *Sephogloeum salvadorae* damage the leaves.

Pharmacological actions and medicinal uses

Biological activity of *S. persica* has been reported from the crude extracts and their different fractions from leaf, stem, root bark, seed and oil. Crude extracts of different parts of *S. persica* have been used as traditional medicine for the treatment of various diseases. The leaves, root bark, fruits and seeds are used for the treatment of cough, fever, asthma and as purgative. Roots are also used for chest diseases while, latex used for treating sores [67-68]. The young roots, stems and branches are used as toothbrush [18]. The plant holds strong antiulcer [69], antifungal [70,71], anti-parasitic, antiviral [72] and antibacterial properties [73]. It is also utilized in most of the dental treatments and cleansers [74,75]. The young branches and leaves are also favorite fodder for camels because of the high water content (15-36 %). Oil from seed is used in rheumatic pain, diabetes and spleen and stomach disorders. The fruits are sweet and peppery in taste with pungent smell and eaten when ripe for medicinal purposes. The oil extracted from the seeds is pale green in color and not meant for edible purposes. The oil has a low percentage of C8 and C10 fatty acids and holds great economic significance [76]. *S. persica* appears to be a potentially valuable oilseed crop for saline and alkali soils, since the seeds contain 30-40 % of oil rich in lauric (C12) and myrestic (C14) acids used in soap, detergent, candles and cosmetic industry [77]. Likewise, seeds of *S. oleoides* contain 40-45% oil, and fruits are also found to be rich sources of calcium [78]. In view of their multiple uses, both species of *Salvadora* are included in restoration programs of many developing countries in Africa and Asia [27,79]. The medicinal uses of different plant parts of *S. persica* are shown in Table 1.

Antibacterial activity

S. persica contains substances that possess plaque inhibiting and antibacterial properties against several types of cariogenic bacteria, which are frequently found in the oral cavity. The growth and acid production of these bacteria is thus inhibited. A comparison of alcohol and aqueous extract of miswak was also made. It was found that alcoholic extract is more effective than aqueous extract for antibacterial activity. In another study, miswak pieces were standardized by size and weight and tested against *Streptococcus mutans*, *Lactobacillus acidophilus*, *Aggregatibacter actinomycetemcomitans*, *Porphyromonas gingivalis*, and *Haemophilus influenzae*. Several reports suggest that the strong antibacterial effect against all bacteria tested is due to the presence of a volatile active antibacterial compounds [70-73].

The effects of the extracts of *S. persica* and derum were examined on the proliferation of Balb/C 3T3 of fibroblast and viability of carcinogenic bacteria. For this, aqueous extracts of miswak and derum were prepared and their effects investigated on the growth of Balb/C 3T3 mouse fibroblast by measuring the mitochondrial dehydrogenase activity. Also the effect on the viability of various cariogenic bacteria was also determined. From the results obtained, it has been concluded that miswak and derum have adverse effects on the growth of cariogenic microorganisms, with derum as more active than miswak [75].

Antiulcer activity

Salvadora persica possessed significant protective action against ethanol and stress-induced ulcers. This study was designed to confirm the antiulcer activity of *S. persica* decoction using optical microscopy. The elements of gastric mucosa tended to be re-established normally in tested rats [69].

Anticonvulsant activity

The effect of *S. persica* as an anticonvulsant was identified by using stem extracts. The stem extracts show the potentiation of sodium pentobarbital activity and on generalized tonic-clonic seizure produced by pentylentertazol (PTZ) on the rat. The extracts of *S. persica* extended sleeping-time and decreased induction-time induced by sodium pentobarbital; in addition it showed protection against PTZ-induced convulsion by increasing the latency period and diminishing the death rate [59].

Antifertility activity

Miswak extract did not have much effect on female mouse fertility, although it caused a significant decrease in the relative weights of the ovary and an increase in the uterine weights. Exposure of male mice to miswak resulted in a 72 % reduction in pregnancies in untreated females impregnated by test males. The relative weights of the testes and preputial glands were significantly increased and that of the seminal vesicles was significantly decreased in test males. The results indicate that miswak has adverse effects on male and female reproduction systems and fertility [80].

Antimycotic activity

Aqueous extracts of miswak can be used to reduce the growth of *Candida albicans,* the causal agent of opportunistic oral infections in humans. Such inhibition lasts for up to 36 hrs at concentrations of 15 % and above [72].

Analgesic effect

Miswak shows analgesic effect and results in decoction when injected into mice [73]. Miswak has been found to be more effective against thermal stimuli than against chemical stimuli and also acts as an analgesic [81-84].

Cytotoxicity

S. persica showed cytotoxic potential on gingival and other periodontal structures [85]. No cytotoxic effect has been shown by a freshly cut and freshly used miswak. However, the same plant used after 24 hrs does contain harmful components. Based on these findings it is recommended that the used portion of the miswak should be cut after it has been used for one day [86-89].

Hypolipidemic activity

The stems of *S. persica* are widely used as tooth cleaning sticks in Arabic countries and decoctions show hypocholesterolemic properties. The effects of prolonged administration of a lyophilized stem decoction of *S. persica* were evaluated in diet induced rat hypercholesterolemic. The preparation was administered for 15 and 30 days and cholesterol, HDL, LDL, and triglycerides plasma levels were assayed. The results showed that the *S. persica* decoction significantly lowered cholesterol and LDL plasma levels in the rats, proving to be more active at 30 days of treatment. It has been observed that *S. persica* decoction is inactive at 18 hrs after treatment, whereas at 27 hrs it is able to reduce cholesterol and LDL plasma levels; in all the experiments HDL and triglycerides were unchanged [90]. The chemical constituents of different plant parts of *S. persica* with their biological activity are shown in Table 2.

Release of calcium and chloride into saliva

Miswak showed immediate and medium-term effect on the composition of mixed saliva [91]. They reported that miswak produced significant increases in calcium (22-fold) and chloride (6-fold), and significant decreases in phosphate and pH, saturation of saliva with calcium inhibits demineralization and promotes demineralization of tooth enamel, whereas high concentration of chloride inhibits calculus formation [92].

Religious prescriptions

In addition to strengthening the gums, preventing tooth decay and eliminating toothaches, the 'miswak' is also said to halt further increase in decay that has already set in. Furthermore, it is said to create a fragrance in the mouth, eliminate bad breath, improve the sense of taste and cause the teeth to glow and shine. In addition, benefits not related to the teeth and gums include sharpening memory, curing headaches, creating a glow on the face of the one who continually uses it, strengthening the eyesight, assisting in digestion and clearing the voice.

Conclusion and future prospects

S. persica has been a good alternative to the toothbrush in Rural India, since it is inexpensive, and readily available. It has many medicinal properties, and is a traditional practice so common in large percentage of our population. Thus it can be recommended as an important and effective tool for oral hygiene. *S. persica* has strong antiulcer, antifungal, anti-parasitic, antiviral and antibacterial properties. Although crude extracts from various parts of *S. persica* have been shown to have medicinal applications from time immemorial, modern drugs can be developed after extensive investigation on modern scientific lines of its bioactivity, mechanism of action, pharmacotherapeutics, toxicity and after proper standardization and clinical trials. Several therapeutically and industrially useful preparations and compounds have also been marketed recently, which has generated enough encouragement among the scientists in exploring more information about this medicinal plant.

Table 1. Medicinal uses of different plant parts of *S. persica.*

Plant part	Medicinal properties	References
Stem bark	Tender twigs are used as toothbrush. It suppresses bacterial growth and the formation of plaque. The tooth stick is also said to relieve toothache and gum disease.	[8,13]
Root bark	It is used to treat gonorrhoea, general body pain, back pain, spleen trouble, headaches and stomach-aches. Roots are also used for chest diseases while, latex used for treating sores.	[67,68]
Leaves	Leaves are fleshy and make good fodder and increase lactation in cows. Leaves are also used for treating cough and asthma, in painful piles, tumors and in scurvy.	[8,19,44]
Fruits	The fruits are sweet and peppery in taste with pungent smell and eaten when ripe for medicinal purposes. The fruit are aphrodisiac, carminative, and emollient, purgative and cures urinary and biliary calculi and arthritis.	[19,39,70,76]
Seeds	Oil from seed is used in rheumatic pain, diabetes, spleen and stomach disorders.	[24,76,77]
Flowers	They are useful in gastric problems, constipation, oligospermia and sexual weakness.	[67,68]

Table 2. Chemical constituents of different plant parts of *S. persica* with their biological activity.

Plant part	Chemical constituents	Biological activity	References
Leaves	Trimethylamine	Diuretic, Analgesic, Anthelmintic, Antibacterial, Antifertility	[19,74,84]
Stem	Octacosanol, Triacantanol, β-Sitosterol, Glucopyranoside, Trimethylamine	Hypocholesterolemic properties, Anticonvulsant, Antibacterial, Antimycotic, Analgesic, Antifertility, Antiulcer, Sedeative	[59,69,80,89]
Roots	Gammamonoclinic sulphur, Benzyl glucosinolate, Salvadourea (a urea derivative), m-Anisic acid, Sitosterol, Benzyl isothiocyanate, Trimethylamine	Antiviral, Antibacterial, Antimycotic, Antifungal, Anti-parasitic	[36,71-73]
Flowers	β-Sitosterol; Glucopyranoside	Stimulant, Laxative, and applied in painful rheumatic conditions	[19,43]
Fruits	N1,N4-bis(phenylmethyl)-2(S)-hydroxy-butanediamine, N-benzyl-2-phenylacetamide	Deobstruent, Carminative, Diuretic, Emollient, Purgative, Lithontriptic and Stomachic properties	[19,70,92]
Seeds	Lauric acid, Myristic and Palmitic acids	Purgative, Diuretic and Tonic	[58-60,73]
Oil	Thujones, Camphor, β-Cymene, Limonene, β-Myrcene, Borneol, Linalool, Bornyl acetate, Caryophyllene	Chronic arthritis, Rheumatic swellings	[24,76]

Table 3. Summary of work done on organogenesis in *S. persica*.

Explant	Mature/ juvenile	Medium + Plant Growth Regulators		References
		Shoot multiplication	Rooting	
Nodal segment	M	BAP (4.0 mgl^{-1}) + IAA (5.0 mgl^{-1})	½ MS + IBA (3.0 mgl^{-1})	[93]
Cotyledonary Node	J	BAP (4.0 mgl^{-1}) + IAA (5.0 mgl^{-1}) + Ads (40 mgl^{-1}) + Glu (100 mgl^{-1}) + Thiamine HCl (10 mgl^{-1})	½ MS + IBA (3.0 mgl^{-1})	[12]
Shoot tip	M	BAP (4.0 mgl^{-1}) + Kn (4.0 mgl^{-1}) + AC (0.3 %)	BA (4.0 mgl^{-1}) + Kn (4.0 mgl^{-1}) + AC (0.3 %)	[45]
Nodal segment	M	BA (0.25 mgl^{-1}) + Kn (0.25 mgl^{-1}) + NAA (0.1 mgl^{-1})	IBA (500 mgl^{-1}) + NOA (100 mgl^{-1})	[56]

AC - activated charcoal, Ads - adenine sulphate, MS - Murashige and Skoog's medium, NOA - 2-naphthoxy acetic acid, Glu - Glutamine

A lot needs to be done however, on various biotechnological aspects in this plant. Since, harvesting from the wild, preparation of drugs leads to loss of genetic diversity, as well as, habitat destruction, for which domestic cultivation can be a viable alternative and may overcome the problems which are common in herbal extracts such as misidentification, genetic and phenotypic variability, extract variability and instability, toxic components and contaminants. However, the use of controlled environments via cell and tissue culture route can overcome cultivation difficulties and could be a means to manipulate phenotypic variation in bioactive compounds and toxins as controlled growth systems also make it feasible to contemplate manipulation of phenotypic variation in the concentration of medicinally important compounds present at harvest with the aim to increase potency, reduce toxin levels and increase uniformity and predictability of extracts.

Rapid plant multiplication and improvement though biotechnological methods are limited for *S. persica*. There has been a significant progress in the use of tissue culture and genetic transformation techniques to alter pathways for the biosynthesis of target metabolites in different medicinal plants; however, no attempt has been made in *S. persica* in this regard. Direct manipulations of DNA sequences to alter gene expression, as well as, pathway modification in this species may also be another area that is ripe for expansion, the potential target for trait manipulation can be the content of active compounds.

Knowledge of the genetic relationships among different accessions is essential for developing appropriate strategies for breeding, germplasm management, and utilization of genetic resources. Further molecular marker assisted selection offers a great potential to improve both agronomic and medicinal traits, as well as, for the recognition of desirable genotypes at an early stage. To date, however, there has not been a single report on molecular marker based approaches for study of genetic diversity or plant improvement in *S. persica*.

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