J. Glob. Innov. Agric. Soc. Sci., 2019, 7(2):39-46.
ISSN (Online): 2311-3839; ISSN (Print): 2312-5225
http://www.jgiass.com

PRESENT STATUS AND FUTURE PROSPECTS OF ENDANGERED SALVADORA SPECIES: A REVIEW

Muhammad Nafees[1,*], Muhammad Adnan Bukhari[2], Muhammad Naveed Aslam[3], Ishtiaq Ahmad[1], Muhammad Ahsan[1] and Muhammad Akbar Anjum[4]

[1] Department of Horticultural Sciences, University College of Agriculture & Environmental Sciences (UCA & ES), The Islamia University of Bahawalpur, Bahawalpur-63100, Pakistan; [2]Department of Agronomy, (UCA & ES), The Islamia University of Bahawalpur, Bahawalpur-63100, Pakistan; [3]Department of Plant Pathology, The Islamia University of Bahawalpur, Bahawalpur-63100, Pakistan; [4]Department of Horticulture, Faculty of Agriculture, Bahauddin Zakariya University Multan, 66000, Pakistan

[*]Corresponding author's e-mail: muhammad.nafees@iub.edu.pk

Salvadora species has been promoted by World Health Organization and as an arid zone climate plant, it is at risk of extinction; however, sustainable high economic, and ecological benefits of limited land resources could be achieved through cultivation of such hardy plants to feed ever increasing population of the world. More than 870 million people of the world are malnourished with 2.6 million children's death every year. As potensive halophyte, Salvadora is an arid horticultural and forest crop, successfully grown in harsh conditions of desert zones of the world in changing climate scenario of the world. All plant parts of Salvadora has medicinal, pharmaceutical, industrial and nutritional importance. Desert ecosystem and arid zones of the world could be conserved through massive plantation of halophytes. However, global warming, less precipitation, water scarcity, population pressure, deforestation and over grazing made Salvadora an endangered species in the world. This review will cover the prospects of Salvadora in agriculture, plantation success on marginal lands, molecular based germplasm conservation and breeding to facilitate viable agricultural practices on earth.

Keywords: *Salvadora persica*, Oleoides, morphological traits, biodiversity, medicinal importance, propagation, conservation.

INTRODUCTION

Pakistan is enriched with halophyte plants, containing 410 of 22,000 species of the world with economic usage in food, fodder, fuel, medicine, ornamentals and chemical industry (Khan and Qasir, 2006). About 19% flora of the country consist of halophytes with major cultivation and distribution in coastal areas, Balochistan plains, moist mountains, deserts, arid mountain sand Potuhar plateau (Khan and Qasir, 2006). Natural vegetation in most parts of the world is reducing for increasing salinity level (FAO, 2011). Moreover, Pakistan, Egypt, India, Australia, South America, Central Asia and Mexico have major areas with trouble shooting issues of water scarcity and salinity (Menzel and Lieth, 1999). Alkalinity and salinity are reducing productivity in arid and semi-arid regions of the world (Boivin *et al.*, 2002), could be reclaimed by developing appropriate biological production system of halophytic horticultural fruit crops (Khan and Qasir, 2006). Salvadora can constitute ≥10% vegetation in natural habitats (Kumar, 1996). Information in this review article is an effort to promote production and conservation of Salvadora species to excel arid zone horticulture and forest industry, improve agro-ecosystem and livelihood of desert zones of world especially the deserts of Thar and Cholistan.

History, origin and species distribution: Persia is the native place where specimens of Salvadora were found and named as *S. persica* originated from Iran, Israel, India, Jordan, Kenya, Nigeria, Egypt, Oman, Chad, Pakistan, Senegal, Somalia, South Africa, Sri Lanka, Saudi Arabia, Sudan, Syrian Arab Republic, Zimbabwe, Uganda, Tanzania Republic of Zambia and Yemen (Bailey, 2003; Wu *et al.*, 2001). The plant is widespread in stream bank vegetation, rivers, thorn shrubs, desert flood plains, grassy savannahs, Thar deserts of Pakistan and western India (Ahmad, 2007; Orwa *et al.*, 2009). The species Persica has replaced *S. oleoides* in southern Punjab and arid and coastal regions of Sindh (Tahir *et al.*, 2010). Salvadora grows well in soils with excessive underground water and tolerate a range of dry soil with mean rainfall of 200 mm. It can easily grow on a variety of sandy to loamy soils with high tolerance in saline and alkaline soils (Orwa *et al.*, 2009), with promising production on sandy coastal soils irrigated with saline water (Dagar *et al.*, 2002).

***Plant taxonomy and description*:** Taxonomic description indicates that Mustard tree (*S. persica* L.) comprised of three genera (*Azima*, *Dobera* and *Salvadora*) and 10 species, named *S. australis, S. biflora, S. capitulate, S. cyclophylla, S. wightii and S. villosa* (Mabberely, 2008). Its generic name had been given in the honour of Juan Salvador Bosca (1598-1681) in 1749 by Dr. Laurent Garcin, a renowned botanist and a plant collector. In the customs of Arab, Japan, Hebrew, Aramaic, Latin, Ethiopia and Indo-Pakistan, the chewing sticks of Salvadora are known by arak (miswak), koyoji, qesam, qisa, mastic, Mefaka and Datun respectively (Bos, 1993; Almas, 1993). Commonly called as Salt bush or Toothbrush tree (English), Mosterdboom (Afrikaans), Yeharer-mefaqya (Amharic), Jhal (Bengali), Arbre a cure-dents (French), Jhak / Kharjal (Hindi), Adhei (Somali), Msuake (Swahili), Kalawa, Karkol (Tamil), Pilu and Karir (Sanskrit), Vann (Punjabi), Jar (Sindhi) and Jall in Saraiki. It is a shrub or small tree with 6-9 m height, short crooked trunk, often twisted or bent with up to 2 m in diameter (Ahmed *et al.*, 2008). Salvadora species like Oleoides are bush or small spreading plant with 6-9 m height, containing twisted or bent short trunk with numerous drooping branches of grey bark with linear or lanceolate fleshy leaves, greenish- white sessile spiked flowers and sweet drupe fruits of various colors depending on species (Tahir *et al.*, 2010; Orwa *et al.*, 2009).

***Morphogenetic diversity*:** Morphological studies of Salvadora plants recognized two species (*S. oleoides* and *S. persica*) in Pakistan (Praveen and Qaiser, 1996). A remarkable variation has been observed in leaf, fruit, seed and pollen characters of *S. persica* in micro-morphological and chemical analysis (Tahir *et al.*, 2010). Leaves of red and white *S. persica* fruits are ovate and lenceolate (respectively), inflorescence is pale greenish and greenish yellow, fruit are Globose-pink to red and Globose–green, while seeds are dark brown and light brown and roughly globular as shown in Figure 1.

***Traditional and medicinal usage*:** Salvadora plants are narrated in Quran and Sunnah as the oral hygiene tool being used as root and shoot sticks for many years (Khafagi *et al.*, 2006; Anonymous, 2009). The Prophet Muhammad (PBUH) used Miswak and its gums to clean the teeth and declared Aarak (*Salvadora Persica* L.) as excellent tooth cleaning stick (Wu *et al.*, 2001; Ezoddini-Ardakani, 2010). This custom was adopted and Islamized by Prophet Muhammad (PBUH) around 543 AD, used by the Arabs, Babylonians in 7000 years ago (Wu *et al.*, 2001; Raed, 1999; Wu *et al.*, 2001) reported that modern toothbrush may be drew from chewing sticks by Babylonians in early 3500 BC as discussed in Greek and Roman literatures. Modern research has recognized various anionic components (antimicrobial agents) in extract of *S. persica* miswak (Darout *et al.*, 2002). Halawany (2012) recorded low concentration of cariogenic bacteria in the saliva of miswak user; moreover, methanol and other heterogeneous compounds of *S. persica* plant are effective against various isolated oral pathogens (Al-Bayati and Sulaiman, 2008) extracted with different chemical procedures (Akhtar *et al.*, 2011). World Health Organization Consensus Report on Oral Hygiene declared that chewing sticks of Salvadora play important role in oral hygiene. Sustainability of natural ecosystem is supported via Salvadora plants by providing habitat for rodents, snakes, lizards (hollow stems), mammals and a variety of birds (Khan, 1996). The established Salvadora plants prevent soil erosion, act as windbreak and withstand on stagnant flood water for months in desert zones because of high spread of its root suckers (Tomar *et al.*, 1998). Non-edible oil extracted from seeds of Salvadora, contain glycosides, terpenes, sterols, alkaloids, flavonoids and volatile oil (Ahmed *et al.*, 2008), benzylamides used in manufacturing detergent and soaps (Khalil, 2006). Sweet succulent Salvadora fruits are excellent source of glucose, fructose and sucrose, however, leaves are used as treatment of joint and knees pain (Monforte *et al.*, 2001). Plants are used as carminative, vulnerary, stomachic, antiseptic and anti-inflammatory and good for spleen, gum, scabies, syphilis, gonorrhea and appetizer in some countries (Ramoliya *et al.*, 2004). Flower and other parts of Salvadora are used in medicines to cure the diseases of toothache, gum problems, skin diseases, snake bites, kidney stones and constipation (Monforte *et al.*, 2001).

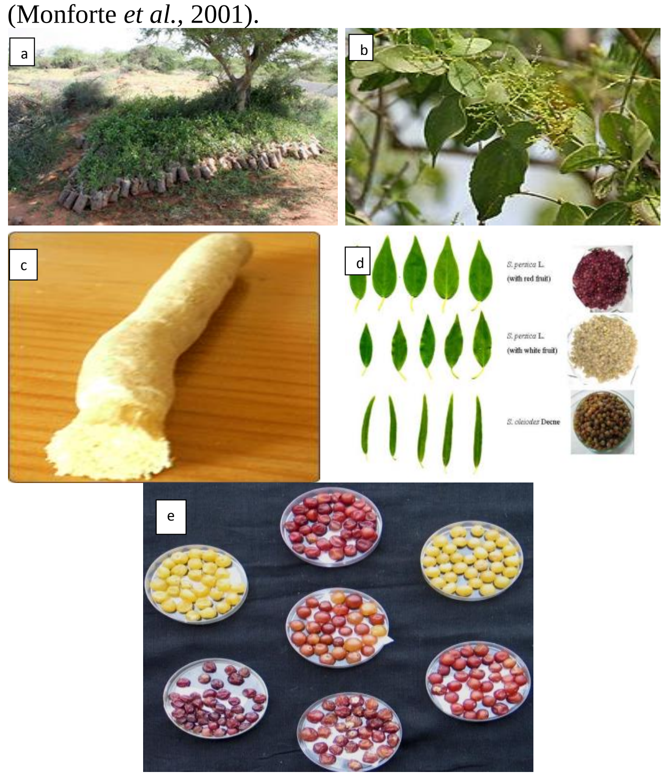

Figure 1. a. Seedlings; b. inflorescence; c. muswak; d. leaves and fruits of *Salvadora* species (Korejo *et al.*, 2010); e. ripped fruits of Salvadora species (Malik *et al.*, 2010).

Table 1. Salvadora plant parts and their chemical composition and pharmacological uses.

Plant parts	Chemical composition	Pharmacological uses	References
Leaves	Indole alkaloid salvadorocine, Benzyl nitrile, Eugenol, Thymol, Isothymol, Eucalyptol, Isoterpinolene, and β-caryophyllene, Glucotropaelin, Different kind of amino-acids, Flavanoids and flavonoid glycosides, Different Organic acids	Carminative, antiseptic, anti-fungal, asthma, cough, rheumatism, virucidal activity, scurvy, piles, leprosy, hepatic disorders, antiscorbutic, deobstruent, liver tonic, diuretic, analgesic, anthelmintic, astringent properties, hypoglycaemic, antimicrobial, anti-bacterial, anti-plasmodial	Abd El Rahman *et al.,* 2003; Al-Otaibi and Angmar, 2004; Joshi *et al.,* 1993; Chaturvedi and Maheshwari, 1998; Ali *et al.,* 1997; Kamil *et al.,* 2000, Bahabri and Salem, 2000, Sarvesh *et al.,* 2007, Trovato *et al.,* 1998, Almas *et al.,* 2005, Al-Bagieh *et al.,* 1997, Ali *et al.,* 2002
Stem	Glucotropaelin, Benzylamides, lignin, flavonoids quercetin	Toothbrush, anti-plaque	Abdel Waheb *et al.,* 1990; Christy *et al.,* 2001
Sticks	Cellulose, hemicelluloses, lignin, Inorganic constituent $CaSO_4$, Ca, Mg, Na, Ti, Cu, Mo, Ni, V, Al, Fe and K	Anti-microbial activity	Bahabri and Salem, 2000; El Sayed, 1995
Stem oil	1,8-cineole (46%), α-caryophyllene (13.4%), β-pinene (6.3%), 9-epi-(E)-caryophyllene	anti-ulcer activity	Alali *et al.,* 2004
Stem bark	Sodium and Chloride	anti-microbial, Anti-spasmodic, anti-arrhythmic and anti-cholinergic activity	Rao *et al.,* 2004
Root	β-sitosterol, m-anisic acid, Salvadourea, Benzylisothionate, Glucotropaelin, sinigrin, Oleic acid, linolic acid and stearic acids	Possess anti-oxidant and anti-inflammatory activity	Rao *et al.,* 2004; Bader and Flamini, 2002; Al-Bagieh, 1998; Christy *et al.,* 2001; Arora and Kaushik, 2006, 2007; Abd El Rahman *et al.,* 2003
Root bark	Alkaloids, silica, salts (mostly as chlorides), resins, Sulfur compounds, tannins and saponins	piles and hepatic disorders	Chopra *et al.,* 1956; Farooqi and Srivastava, 1968
Root and stem extracts	chloride, sulphate, thiocyanate and nitrate	anti-microbial, anti-caries, antispasmodial, anticonvulsant	Hattab 1997; Almas 2001; Al-Bagieh *et al.,* 1994; Darout *et al.,* 2000
Seed oil	lauric acid, myristic acid, palmitic acid, stearic acid, oleic acid, linolic acid, malvalic acid and sterculic acid	Rheumatism	Khan *et al.,* 1972; Hosamani and Pattanashettar, 2002; Anonymous, 1972
Fruit and flowers	rutin	Carminative, diuretic, stomachic, rheumatism, de-worming, leprosy, gonorrheae	Anonymous, 1972; Khan *et al.,* 1972

***Chemical composition and usage in pharmaceutics*:** Chemists, pharmaceutical companies and other researchers did a lot of research on the importance of different plant parts of Salvadora. The plant contains various organic compounds used in the medicine and declared as it as excellent pharmaceutical plant. Details of Salvadora plant parts, their chemical composition and pharmacological uses along with references is mentioned in Table 1.

***Production of Salvadora on marginal soils*:** Flooding drives plants toward hypoxia (oxygen limitation) and salinity mimic drought condition for the plants thus reduce productivity even with intensive inputs. Researchers are frequently studying the accumulation of salts in tissues of plants growing in marginal lands with objective to get benefits from such saline, waterlogged and barren lands, covering largest area in all over the world. (Patel *et al*., 2010). Salinity reduce seedling growth even damage vegetation through osmotic effect, ions toxicity and nutritional deficiency; however, plant can help in rehabilitation on gypsum mined surfaces in desert zones (Sharma and Gough, 1999).

Salinity and alkalinity resulting insufficient agricultural production (Boivin *et al.,* 2002), is increasing rapidly with high evapotranspiration, poor quality irrigation water and low precipitation (Flowers *et al.,* 1997). This will affect 50% arable land in 2050, if intensive vegetation practices are not planned in desert zones of the world. Salvadora species are highly salt tolerant, classified as mesomorphic xerophytes and facultative halophytes (Rao *et al.,* 2004). It is industrially important oilseed crop in irrigated and non-irrigated desert zones of the world (Reddy *et al.,* 2008). Salvadora seedlings can successfully be grown for the restoration of marginal lands (Tomar *et al.,* 1998). It is excellent bio-drainage plant useful to minimize waterlogging and salinity (Kapoor, 1998), suggested to promote its plantation in salt affected areas for soil reclamation (Tewari *et al.,* 1997). Seedling emergence was significantly delayed with increase in salinity (Ramoliya *et al.,* 2004), however, early seedling emergence could be ensured in wet soils, help to reduce the effect of salinity. Thus, moisture conservation in the soils of desert zones in monsoon season or canal water supply may promote Salvadora vegetation in Thar and Cholistan deserts of Indo-Pakistan (Kasera *et al.,* 2003; Ramoliya and Pandey, 2002). The growth of agriculture sector could be improved by promoting the plantation of oil rich Salvadora plants in saline and alkali soils of desert zones (Eganathan *et al.,* 2006) contains 40–45% industrial and edible oil in seeds (Reddy *et al.,* 2007). Plant height, spread and yield significantly high on saline as compared to alkali soils without any effect on oil contents in seeds (Muppala *et al.*, 2008). Seed yield for oil extraction was significantly high on saline as compared to alkali soils (Reddy *et al.,* 2008). Oil extracted from Salvadora seeds is a good source of industrial oil for economic and ecological benefits, not suitable for conventional farming (Ramoliya and Pandey, 2002). The Salvadora fruits are the grapes of desert and arid zones of the world with pulp containing glucose, fructose and sucrose (Khan and Shaukat, 2006). Thus, it is utmost required to reclaim effective soils with intensive plantation of salinity and drought tolerant halophytes by producing seedlings of Salvadora through seed and shoot cuttings.

***Propagation, breeding and germplasm conservation*:** Propagation success in Salvadora is poor through seed for the presence of high oil contents in it. Regeneration and propagation issue are the major obstacle in worldwide spread of this crop with only 30% viability through seed (Mathur *et al*., 2002a,b, 2010); moreover, prolong seed storage is not possible because of high oil contents which reduce its viability and easily infestation by insects and pathogens (Phulwaria *et al.,* 2011; Jindal *et al.,* 2006). Cultivar characters could not be maintained in sexual propagation with high degree of genetic diversity because the crop is highly cross-pollinated in nature (Phulwaria *et al.,* 2011). The seeds collected from succulent healthy fruits during April-May were kept wet to produce seedling in June (Khan and Qaiser, 2006; Korejo, 2010), germinated after one month in saline soils (Ahmed *et al.,* 2008; Ramoliya *et al.,* 2004). Nitrogen and gypsum application in sandy loam alkali soil during the monsoon season can support to enhance the growth and establishment of Salvadora seedlings (Arya *et al.,* 2005). Seed scarification in hands or rubbing in gunny bag, keeping overnight for shade drying, pretreating in cold water and sowing at 0.5 cm depth, could increase germination rate in *Salvadora oleoides* (Mertia and Kunhamu, 2003). Seed density and volume had direct effect on time and intensity of germination, moreover, early and high germination was recorded in heavy and healthy seeds (Dagar *et al.,* 2004). In proper field conditions, 15 gram Salvadora seeds can cover one hectare land with 5x5 meter spacing between trees for proper height and diameter development (Kasera *et al.,* 2003). Ploughing, leveling and fertilizer (manuring and chemical) application in June is required for good fruit production. Weeds are eliminated by hoeing after every 20 days in rainy season up to 3-4 years of plant age. Plant height, collar diameter, biomass, root yield and harvest index increased by maintaining fortnightly and monthly irrigation schedule during summer and winter months, respectively (Kasera *et al.,* 2003).

Salvadora propagation through tissue culture is successfully used for cloning of desired genotypes (Cheliak and Rogers, 1990) to produce plants of desired traits. Cotyledonary node (Mathur *et al.,* 2002a) and explants taken from two-year-old *S. persica* (Mathur *et al.,* 2002b) used *in vitro* propagation for somatic embryogenesis and plantlets regeneration. The success of plant regeneration is too low to practice commercially in various saline and drought resistant horticultural crops (Bonga *et al.,* 2010). Genetic expression of young seedlings in tissue culture are not entirely branded, thus shoots from adult explants are used to study genetics of species (Bonga *et al.,* 2010). Selection of explant and shoot culture are important elements in cloning and maintenance of clonal purity (Bonga *et al.,* 2010). Recalcitrant contamination occurs in Salvadora seedlings emerged from seeds harvested in September to March, while, complete surface sterilization of such explants is not possible, resulting in slow growth of plants for the accumulation of growth inhibitors in winter season (Phulwaria *et al.,* 2011). Age and climatic condition of explant directly effect on callus induction because of high accumulation of recalcitrant microbes in shoots of older branches (Phulwaria *et al.,* 2011). Salvadora shoots lopped during winter are best as explant for regeneration in tissue culture (Rathore *et al.,* 2005). Most effective cytokinins in cultural media is 6-benzyladenine than Kinetin in several horticultural and forest plants, result as rapid bud induction, which is requisite for cloning in Salvadora (Zhang *et al.,* 2010). Rejuvenation in micro-cloning of halophytes was completed by repeated transferring of mother explants (Deora and Shekhawat, 1995). The cloned shoots of Salvadora treated with IBA develop roots within short period, resulting to reduce the steps in rooting and hardening of plants, save time, labor cost and resources (Phulwaria *et al.,* 2011). Generally ex-vitro developed roots have numerous root hairs, beneficial in plant adaptation during acclimatization (Sharma *et al.,* 2007) and better suited to tolerate the environmental stresses (Tiwari *et al.,* 2002).

Most molecular marker techniques are applied to evaluate genetic diversity and association analysis for germplasm conservation and variety improvement (Agarwal *et al.,* 2008). Morpho-chemical traits and molecular markers are key source of germplasm diversity estimation (Mars and Marrakchi, 1999; Jalikop, 2010); moreover, molecular linkage based association analysis has been successfully utilized in variety improvement program in fruits of arid zones like pomegranates (Jalikop, 2010). Biological and genetic improvement of plant germplasm could be achieved from vegetation growing in diverse agro-ecological conditions. Morpho-chemical diversity in Salvadora germplasm was previously verified, however, molecular based diversity estimation and conservation has potential to prevent complete elimination of this highly useful halophyte (Arora *et al.,* 2010). The isozyme detection and molecular analysis were carried out to estimate morphological and molecular diversity in plants. DNA markers are being successfully used to know the basis of genetic mechanisms and gene sequencing for advance breeding programs (Pritchard *et al.*, 2000). Allele-specific and co-dominant molecular markers (SSR) are most reliable source to detect molecular diversity and relationship of organisms, used in breeding and variety improvement program (Zhang *et al.,* 2008). Three group of pistachio germplasm diversity were confirmed using seven AFLP primers which provided useful information in variety improvement and sustainable conservation of pistachio in Syria (Basha *et al.,* 2007). Genetic distance in Bread fruit germplasm was measured to improve effective breeding (Ravi *et al.,* 2011) studied the molecular basis of drought tolerant linked traits in groundnut. These informations could successfully be utilized in breeding of endangered minor fruits like Salvadora to sequence the drought and salinity resistant genes.

Conclusion**:** There is 19% flora of Pakistan which consist of various halophytes, facing water scarcity, salinity, deforestation, over grazing and adverse agro-climatic conditions for survival. Plantation of Salvadora species could not only increase vegetation but also provide food, forage, fodder and medicine for the people of desert zones to minimize food shortage. It is widespread in thorn shrubs, river and stream bank vegetation in Thar, Cholistan, Rajasthan and various other parts of Indo-Pakistan and widely distributed from Africa to China. Commercial propagation of Salvadora is done through seed and root suckers in nurseries, however, micro propagation methods were developed for rapid shoot multiplication and root induction in Salvadora. Regeneration systems developed from nodal explants, could be used in multiplication of genetically modified plants of Salvadora species. This technical note will provide guideline to promote plantation of Salvadora species in Thal-Thar and various desert zones to improve agro-ecological conditions and livelihood of ever-increasing population of the world by improving vegetation of livestock and industry.

REFERENCES

Akhtar, J., K. Siddique, S. Bi and M. Mujeeb. 2011. A review on phytochemical and pharmacological investigations of miswak (*Salvadora persica* L.). J. Pharm. Biol. Allied Sci. 3:113-117.

Ahmed, S.S., S.E.E. El-Gengaihi, M.S. Ibrahim and E. Schnug. 2008. Preliminary phytochemical and propagation trial with *Salvadora persica* L. Agri. Forest. Res. 58:135-138.

Anonymous. 2009. Food of the Prophet (Sallallaho Alayhi Wasallam). Dar-ul-Iman healing Available online at http://chishti.org/foods_of_the_prophet.htm. Accessed March 23

Arya, R., K.R. Chaudhary and R.R. Lohara. 2005. Effect of nitrogen and gypsum on the establishment and early growth of *Salvadora persica* L. on salt affected soils under hot arid conditions in India. For. Trees Livelihoods 15:291-306.

Al-Bayati, F. and K. Sulaiman. 2008. *In vitro* antimicrobial activity of *Salvadora persica* L. extracts against some isolated oral pathogens in Iraq. Turk. J. Biol. 32:57–62.

Agarwal, M., N. Shrivastava and H. Padh. 2008. Advances in molecular marker techniques and their applications in plant sciences. Plant Cell Rep. 27:617–631.

Aggarwal, J.S. 1954. Khakan fat (Pilu oil) as a substitute for coconut oil in soap. J. Oils Oilseeds 7:5-6.

Almas, K. 1993. Miswak (Chewing stick) and its role in oral health. Postgraduate Dentist 3:214-218.

Arora, J., S. Goyal and K.G. Ramawat. 2010. Biodiversity, Biology and Conservation of Medicinal Plants of the Thar Desert, pp.1-7. In: K.G. Ramawat (eds.), Desert Plants: Biology and biotechnology. Springer-Verlag Berlin Heidelberg.

Addel-Rahman, H.F., N. Skaug, A.M. Whyatt and G.W. Francis. 2003. Volatile compounds in crude Salvadora persica extracts. Pharmac. Biol. 41:399-404.

Al-Otaibi, M. and B. Angmar. 2004. Oral hygiene habits and oral health awareness among urban Saudi Arabians. Oral Health Prev. Dent. 2:389-96.

Abdel-Wahab, S.M., M.A. Selim, N.M. Ei-Fiki and B.M.A. Ei-Falaha. 1990. Investigation of glucosinolates of Salvadora persica. Bull. Fac. Pharm. 28:63-66.

Ali, A.A., M.H. Assaf and E. Shanawany. 1997. Flavonoid glycosides from the leaves of *Salvadora persica* L. Bull. Pharm. Sci. 20:181-186.

Almas, K., N. Skaug and I. Ahmad. 2005. *In vitro* antimicrobial comparison of miswak extract with commercially available non-alcohol mouthrinses. Int. J. Dent. Hyg. 3:18-24.

Al-Bagieh, N.H. 1998. Effect of benzylisothionate on the growth and acid production of *Candida albicans*. Biomed. Lett. 58:139-145.

Al-Bagieh, N.H. and K. Almas. 1997. *In vitro* antimicrobial effects of aqueous and alcohol extracts of miswak. Cairo Dental J. 13:221-224.

Ali, H., G.M. Konig, S.A. Khalid, A.D. Wright and R. Kaminsky. 2002. Evaluation of selected Sudanese medicinal plants for their *in vitro* against hemoflagellates, selected bacteria, HIV-1-RT and tyrosine kinase inhibitory and for toxicity. J. Ethno. Pharmac. 83:219-228.

Alali, F., M. Hudaib, T. Aburjaj, K. Khairallah and N. Al-Hadidi. 2004. GC-MS analysis and antimicrobial activity of the essential oil from the stem of the Jordanian toothbrush tree *Salvadora persica*. J. Pharm. Biol. 42:577-580.

Anonymous. 1972. The Wealth of India-Raw Materials. IX PID CSIR New Delhi; pp.193-195.

Arora, S. and D. Kaushik. 2007. Free radial scavenging activity of *Salvadora persica* Linn. Asian J. Chem. 19:4638-4644.

Arora, S. and D. Kaushik. 2006. Anti-inflammatory activity of *Salvadora persica* Linn. J. Sci. Pharm. 7:89-93.

Bonga, J.M., K.K. Klimaszewska and P.V. Aderkas. 2010. Recalcitrance in clonal propagation, in particular of conifers. Pl. Cell Tiss. Org. Cult. 100:241–254.

Basha, A.I., S. Padulosi, K. Chabane, A.H. Hassan, E. Dulloo, M.A. Pagnotta and E. Porceddu. 2007. Genetic diversity of Syrian pistachio (*Pistacia vera* L.) varieties evaluated by AFLP markers. Genet. Resour. Crop Evol. 54:1807-1816.

Bailey, H. 2003. The Standard Encyclopedia of Horticulture, Vol. II. New York; Macmillan Co; pp.14-15.

Bos, G. 1993. The miswak, an aspect of dental care in Islam. Med. Hist. 37:68-79.

Boivin, P., F. Favre, C. Hammecker, J.L. Maeght, J. Delariviere, J.C. Poussin and M.C.S. Wopereis. 2002. Processes driving soil solution chemistry in a flooded rice-cropped vertisol: analysis of long-time monitoring data. Geoderma 110:87-107.

Cheliak, W.M. and D.L. Rogers. 1990. Integrating biotechnology into tree improvement Programs. Can. J. For. Res. 20:452-463.

Dagar, J.C., H. Bhagwan and Y. Kumar. 2004. Seed germination studies of Salvadora persica and Jatropha curcas. Ind. J. For. 27:283-289.

Darout, I., J. Albandar, N. Skaug and R. Ali. 2002. Salivary microbiota levels in relation to periodontal status, experience of caries and miswak use in Sudanese adults. J. Clin. Periodontol. 29 :411-420.

Deora, N.S. and N.S. Shekhawat. 1995. Micropropagation of *Capparis decidua* (Forsk.) Edgew- a tree of arid horticulture. Plant Cell Rep. 15:278-281.

Eganathan, P., S.R. Subramanian, R. Latha and R.C. Srinivasa. 2006. Oil analysis in seeds of *Salicornia brachiata*. Ind. Crops Prod. 23:177-179.

Ezoddini-Ardakani, F. 2010. Efficacy of Miswak (*Salvadora persica*) in preventing dental caries. Health. 2:499-503.

Farooqi, I. 1998. Ahadith Mein Mazkoor Nabatat, Adwiya Aur Ghizain. Ilm-o-Irfan Publishers, 9 lower Mall, Aqab Mian Market, Urdu Bazar Lahore; pp.151-168.

Flowers, T.J., A. Garcia, M. Koyarna and A.R. Yeo. 1997. Breeding for salt tolerance in crop plants—the role of molecular biology. Acta Physiol. Plant. 19:427-433.

Heuze, V. and S. Giger-Reverdin. 2011. Saltbush (*Salvadora persica*). A program by INRA, CIRAD, AFZ and FAO. Available online at http://www.feedipedia.org/node/97

Halawany, H.S. 2012. A review on miswak (*Salvadora persica* L) and its effect on various aspects of oral health. The Saudi Dental J. 24:63-69.

Jindal, S.K., M. Singh and R. Sivadasan. 2006. Variability for seed size, oil content, seed germination and juvenile traits in germplasm collections of *Salvadora oleoides* Decne from arid parts of Gujarat. Ann. Arid Zone 45:53-58.

Joshi, A.J., M. Krishankumar and B.S. Mali. 1993. Seasonal changes in proteins, amino acids and minerals in *Salvadora persica* L. with reference to saline habitats. Ind. J. Plant Physiol. 36:202-204.

Korejo, F., S.A. Ali, S.T. Syeda, M.T. Rajput and M.T. Akhter. 2010. Comparative morphology and biochemical studies of Salvadora species found in Sindh, Pakistan. Pak. J. Bot. 42:1451-1463.

Jalikop, S.H. 2010. Pomegranate Breeding: Fruit, Vegetable and Cereal Science and Biotechnology. Global Sci. Books 4:26-34.

Khalil, A.T. 2006. Benzylamides from Salvadora persica. Archives Pharm. Res. 29:952-956.

Khan, M.A. and M. Qaiser. 2006. Halophytes of Pakistan: Distribution, ecology, and economic importance. In: M.A. Khan, H. Barth, G.C. Kust and B. Boer (eds.), Sabkha Ecosystems, Vol. II. Springer, Netherlands; pp.129-153.

Khan, D. and S.S. Shaukat. 2006. The fruits of Pakistan: diversity, distribution, trends of production and use. Int. J. Biol. Biotechnol. 3:463-499.

Kasera, P., J. Prakash and D. Chawan. 2003. Effects of spacing and irrigation levels on growth and biomass production in Salvadora persica. J. Trop. For. Sci. 15:626-629.

Kapoor, A.S.1998. Prevention of soil salinisation of irrigated lands in dry arid regions with the help of plantations. Water and Energy Inter. 55:27-35.

Kumar, S. 1996. Trends in structural compositional attributes of dune-interdune vegetation and their edaphic relations in the Indian desert. Vegetation 124:73-93.

Khan, A.U. 1996. Appraisal of ethno-ecological incentives to promote conservation of Salvadora oleoides Decne: The case for creating a resource area. Biol. Conserv. 75:187-190.

Khafagi, I., A. Zakaria, A. Dewedar and K. El-Zahdany. 2006. A voyage in the world of plants as mentioned in the Holy Quran. Inter. J. Bot. 2:242-251.

Khan, S.A., M.I. Qureshi and M.K. Bhatty. 1972. Fatty acids of indigenous resources for possible industrial applications. IV. Species of Salvadoraceae family. Pak. J. Sci. Ind. Res. 15:402-404.

Kamil, M., F. Ahmad, A.F. Jayaraj, C. Gunasekhar, S. Thomas, M. Habibullah and K. Chan. 2000. Isolation and identification of a flavanol glycoside using high speed counter current chromatographic technique from the leaves of *Salvadora persica*. Pak. J. Sci. Ind. Res. 43:255-257.

Mathur, A, A.K. Mathur and A. Gangwar. 2002a. efficacy of some cell culture approaches applied for micropropagation conservation and secondary metabolite production in ginseng (*Panax* spp.). In: S.K. Nandi, L.M.S. Palani and A. Kumar (eds.), Role of Plants Tissue Culture in Biodiversity Conservation and Economic Development. Gyndodayan Prakashan, Nainital, India; pp. 267-275.

Mathur, A., A.K. Mathur, A. Gangwar, S. Yadav and P. Verma. 2010. Anthocyanin production in a callus line of Panax sikkimensis ban. *In Vitro* Cell. Devel. Biol.- Plant 46:13-21.

Mabberley, D.J. 2008. Mabberley's Plant-Book: A Potable Dictionary of Plants, their Classification and Uses, 3rd Ed. Cambridge University Press: vii-xvii, 1-1021.

Merkle, S.A. and J.F.D. Dean. 2000. Forest biotechnology. Curr. Opin. Biotechnol. 11:298-302.

Malik, S.K., R. Chaudhury, O.P. Dhariwal and D.C. Bhandari. 2010. Genetic Resources of Tropical Underutilized Fruits in India. NBPGR, New Delhi; pp.168.

Malik, S., A. Syed, S. Haider, S. Imtiaz and M. Anjum. 1987. Salvadoricine, a new alkaloid from the leaves of *Salvadora persica*. Tetrahedron Lett. 28:163-164.

Mertia, R.S. and T.K. Kunhamu. 2003. Quick raising of *Salvadora oleoides* (Decne) saplings. In: P. Narain, S. Kathju, A. Kar, M.P. Singh and P. Kumar (eds.), Human Impact on Desert Environment. CAZRI, Jodhpur, India; pp.397-399.

Monforte, M.T., N. Miceli, M.R. Mondello, R. Sanogo, A. Rossitto and E.M. Galati. 2001. Antiulcer activity of *Salvadora persica* on experimental ASA-Induced Ulcer in rat: Ultrastructural modifications. Pharma. Biol. 39:289–292.

Mars, M. and M. Marrakchi. 1999. Diversity of pomegranate (*Punica granatum* L.) germplasm in Tunisia. Genet. Resour. Crops Evol. 46:461–467.

Menzel, U. and H. Lieth. 1999. Halophyte Database Vers. 2.0. Halophyte uses in different climates. I: Ecological and ecophysiological studies. Prog. Biomet. 13:77-88.

Muppala P.R., M.T. Shah and S. Jinalal. 2008. *Salvadora persica*, a potential species for industrial oil production in semiarid saline and alkali soils. Ind. Crops Prod. 28:273–278.

Orwa, C., A. Mutua, R. Kindt, R. Jamnadas and S. Anthony. 2009. Agro-forest tree Database: A tree reference and selection guide version 4.0. Available online at http://www.worldagroforestry.org /sites/treedatabase.asp

Patel, A.D., N.S. Panchal, I.B. Pandey and A.N. Pandey. 2010. Growth, water status and nutrient accumulation of seedlings of *Jatropha curcas* L. (Euphorbiaceae) in response to soil salinity. Anales de Biologia 32:59-71.

Parveen, A. and M. Qaiser. 1996. Pollen Flora of Pakistan-vi. Salvadoraceae. Pak. J. Bot. 28:151- 154.

Pritchard, J.K., M. Stephens and P. Donnelly. 2000. Inference of population structure using multilocus genotype data. Genetics 155:945-959.

Phulwaria, M., K. Ram, P. Gahlot and N.S. Shekhawat. 2011. Micro propagation of *Salvadora persica*: A tree of arid horticulture and forestry. New Forests 42:317-327.

Qureshi, S. 1972. Salvadoraceae in Flora of West Pakistan. Source??? Karachi; 29:1-4.

Ronse, D.C.L. and L. Wanntorp. 2009. Floral development and anatomy of Salvadoraceae. Ann. Bot. 104:913-23.

Ramoliya, P.J., H.M. Patel and A.N. Pandey. 2004. Effect of salinization of soil on growth and macro- and micro-nutrient accumulation in seedlings of *Salvadora persica*. Forest. Ecol. Manage. 202:181-193.

Ramoliya, P.J. and A.N. Pandey. 2002. Effect of increasing salt concentration on emergence, growth and survival of seedlings of *Salvadora oleoides* (Salvadoraceae). J. Arid Environ. 51:121-132.

Rao, G.G., A.K. Nayak, A. R. Chinchmalatpure, A. Nath and V.R. Babu. 2004. Growth and yield of *Salvadora persica*, a facultative halophyte grown on saline black soil (*Vertic haplustept*). Arid Land Res. Manag. 18:51-61.

Rao, A.V. and J.C. Tarafdar. 1998. Selection of plant species for rehabilitation of gypsum mine spoil in arid zone. J. Arid Environ. 39:559-567.

Rathore, J.S., M.S. Rathore and N.S. Shekhawat. 2005. Micropropagation of *Maerua oblongifolia* liana of arid areas. Phyto-morphology 55:241-247.

Reddy, M.P., M.T. Shah and S.J. Patolia. 2008. *Salvadora persica*, a potential species for industrial oil production in semiarid saline and alkali soils. Ind. Crops Prod. 28:273-278.

Raed, I., B.D.S. Al-Sadhan, B.D.S. Khalid-Almas. 1999. Miswak (Chewing stick): A cultural and scientific heritage. Saudi Dental J. 11:80-88.

Ravi, K., V. Vadez, S. Isobe, R.R. Mir, Y. Guo, S.N. Nigam, M.V. Gowda, T. Radhakrishnan, D.J. Bertioli and S.J. Knapp. 2011. Identification of several small main-effect QTLs and a large number of epistatic QTLs for drought tolerance related traits in groundnut (*Arachis hypogaea* L.). Theor. Appl. Genet. 122:1119-1132.

Sharma, V. and K.G. Ramawat. 2013. Salinity-induced modulation of growth and antioxidant activity in the callus cultures of (*Salvadora persica*). Biotechnol. 3:11-17.

Sharma, T., M. Modgil and M. Thakur. 2007. Factors affecting induction and development of in vitro rooting in apple rootstocks. Ind. J. Exp. Biol. 45:824-829.

Sharma, K.D. and L.P. Gough. 1999. Rehabilitation of mined surfaces in an extremely arid climate, north-west India. In: D. Eldridge and D. Freudenberger (eds.), People and Rangelands: Building the future. Proc. VI Int. Rangeland

Cong., Townsville, Queensland, Australia, 19-23 July, 1999. Vol. 1 and 2; pp.986-987.

Sarvesh, P., R. Chauhan, A.A Siddiqui and S.P.J. Sharma. 2007. Evaluation of antifungal activity of *Salvadora persica* Linn. leaves. Nat. Prod. Res. 6:372-374.

Tahir, S.S., M.T. Rajput and F. Korejo. 2010. A new species of Salvadora (Salvadoraceae) from Sindh, Pakistan. Pak. J. Bot. 42:63-66.

Tomar, O.S., R.K. Gupta and J.C. Dagar. 1998. Afforestation techniques and evaluation of different tree species for waterlogged saline soils in semiarid tropics. Arid Soil Res. Rehabilitation 12:301-316.

Tewari, V.P., M.L. Arrawatia and V.S.K. Kumar. 1997. Problem of soil salinity and waterlogging in Indira Gandhi Canal area of Rajasthan State. Ann. Biol. 13:7-13.

Tiwari, S.K., J.P. Tiwari and E.A. Siril. 2002. An improved micropropagation protocol for teak. Pl. Cell Tiss. Org. Cult. 71:1-6.

Trovato, A., E.M. Galati, A. Rossitto, M.T. Monforte, A. Aquino and A.M. Forestieri. 1998. Hypoglycemic effect of *Salvodora persica* in the rat. Phytomedicine 5:129-132.

Wu, C., I. Darout and N. Skaug. 2001. Chewing sticks: timeless natural toothbrushes for oral cleansing. J. Periodontal. Res. 36:275-284.

Zhang, H., K.J. Horgan, P.H. Reynolds and P.E. Jameson. 2010. 6-Benzyladenine metabolism during reinvigoration of mature *Pinus radiata* buds *in vitro*. Tree Physiol. 30:514-526.

Zhang, J., T.J. Zhao and J.Y. Gai. 2008. Association analysis of agronomic trait QTLs with SSR markers in released soybean cultivars. Acta Agron. Sin. 34:205922069.