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REVIEW ARTICLE

A review on biological activities and conservation of endangered medicinal herb *Nardostachys jatamansi*

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Abstract: *Nardostachys jatamansi* DC also known as Indian Spikenard or Indian Valerian, is a valued medicinal plant of family Valerianaceae. This rhizome bearing plant is native of the Himalayas of India and Nepal and preferably found from 2200 m to 5000 m asl in random forms. The extract of rhizome is widely used in the formulation of traditional Ayurvedic medicines as well as modern herbal preparations for curing several ailments. In some parts of their range owing to overharvest for medicinal use and trade, habitat degradation and other biotic interferences leads plant into threat category. In India the observed population of jatamansi declines of 75-80% and classified as Endangered in Arunachal Pradesh, Sikkim and Himachal Pradesh and Critically Endangered in Uttarakhand. Realizing the high level of threat CITES has notified *N. jatamansi* for its schedule care to ensure the conservation. Hence, emphasis should be given on proper conservation and apply biotechnological tools for sustainable use which in turn help to save it from extinction. In view of immense importance in the present review an attempt has been made to focus on the distribution, medicinal value and conservation aspects of this valuable plant.

Keywords: Conservation; Diversity; Endangered; Medicinal Plant; *Nardostachys*; Random amplified polymorphic DNA (RAPD).

Introduction

Nardostachys jatamansi DC is a small, perennial, rhizomatous, herb which grows in steep, moist, rocky, undisturbed grassy slopes of India, Nepal, China, Tibet and Bhutan from 2200 m to 5000 m above sea level (Ghimire et al. 2005). It is commonly known as jatamansi, Indian nard, balchar or spikenard. Its rhizomes are used in traditional medicines in different medicinal system (Yang 1996). Jatamansi has been widely used for medicine and in perfumery for centuries in India. It is valued for many medicinal properties such as anti-lipid peroxidative, hypolipidemic, antioxidant, hepatoprotective, sedative, tranquilizing, antihypertensive, anti-inflammatory, antidepressant-like activity, anticonvulsant activity and hypotensive properties, anti-asthmatic and anti-estrogenic activity (Rahman et al. 2011a). Apart from this it is also used for the treatment of hair loss, growth and luster (Bagchi et al. 1991), and several nervous disorders such as epilepsy, neurosis, insomnia, excitation, alzheimer's disease, learning and memory disorders (Joshi and Parle 2006; Rahman et al. 2011a). Their extracts also possess antispasmodic and stimulant properties which are useful in the treatment of fits and heart palpitations and it can also be used to regulate constipation, urination, menstruation and digestion (Anon 1993).

Due to several medicinal properties, overexploitation has been carried out continuously and now the plant has entered in endangered status. Conservation Assessment and Management Plan

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(CAMP) workshops in India reported that observed population declines of 75-80% and classified jatamansi in different threatened categories. Hence, such a multitude utility medicinal herb needs conservation of biodiversity to maintain their population.

Origin and geographical distribution

Valerianaceae the family of order Dipsacales contains 400 species and is mainly distributed in temperate regions (Donogue et al. 2003). The suggested number of genera varies from one to sixteen (Graebner 1906) but recent investigation comprises eight genera (Eriksen 1989). *Nardostachys* is a primitive genus having restricted geographical distribution in India (Jain and Rao 1983), South West China (Anon 1987), Nepal (Shrestha and Joshi 1996), Bhutan (Pradhan 1993), Sikkim (Chauhan 1999), Myanmar, Afghanistan and Pakistan (Anon 1997). Previously the genus *Nardostachys* comprised 4 species i.e. *Nardostachys jatamansi*, *N. grandiflora*, *N. chinensis* and *N. gracilis* but currently *Nardostachys chinensis*, *N. grandiflora* and *N. gracilis* are considered as synonyms of *N. jatamansi* (Jain 1994; Lange and Schippmann 1999). The herbs are widely distributed on undisturbed slopes (2200–5000m asl) of alpine regions of Himalayas (Amatya et al. 1995). It grows well on open, stony and grassy slopes with a 25° - 45° slope. The existing status of the species and variations in its performance in different habitats were studied in selected sites in Uttarakhand, West Himalaya. Dripping moss-laden rocks and moist boulders are the most preferred habitats of this plant. The mean density in two contrasting slopes differed, showing relatively higher density on west-facing slopes. Study reports that several biological and environmental features decide the favorable site of this plant and their abundance (Airi et al. 2000).

Ploidy level

Jatamansi is a natural deploid species indigenous to the Indian Himalaya. It has basic chromosome number X= 13 and the diploid chromosome number 2n=26. It has total nucleosomal DNA content of about 3.49 $(pg)^2$ (Hidalgo et al. 2010).

Current Status

Reports suggest that the species has become endangered due to over-exploitation of rhizomes for its high medicinal value, habitat degradation and other biotic interferences in its distribution ranges. Low level of viabilities in seeds, germination and storage of this plant under natural condition also play an important role in threat status of this plant. Conservation Assessment and Management Plan (CAMP) workshops in India reported that observed population declines of 75-80% and classified jatamansi as endangered (Arunachal Pradesh, Sikkim and Himachal Pradesh) and Critically Endangered (Uttarakhand) (Mulliken and Crofton 2008). Jatamansi was assessed to be vulnerable at a CAMP workshop in Nepal in 2001 (Anon 2001). Due to the high level of threat, Convention on International Trade of Endangered Species (CITES) has notified jatamansi for its schedule care. Studies on the viability, germination and storage of jatamansi seeds were done to minimize some pressure on the survival of this critically endangered medicinal plant (Chauhan and Nautiyal 2007).

Morphology and physiological description

Jatamansi is a perennial, dwarf, hairy, rhizamatous herb, densely covered with fibrous or lamellar remains of old sheaths. Its flowering stems are 5-50 cm tall. Rosulate leaves narrowly spatulate or linear-oblanceolate, 3-25 cm long, 0.5-2.5 cm wide, with 3 parallel veins, glabrous or sparsely puberulous, base attenuate into petiole nearly equal to leaf blade in length, margin entire, apex obtuse. Leaves are cauline, lower ones elliptic to obviate; upper ones sessile, oblanceolate to lanceolate, sometimes sparsely serrate. Capitula of cymes, terminal, 1.5-2 cm broad; main inflorescence rachises and lateral rachises sometimes elongated; involucral bracts 4-6, lanceolate; bracts narrowly ovate to ovate, nearly equal to flowers in length; bracteoles 2, small. Its calyx are 5-lobed; lobes semiorbicular to triangular-lanceolate, enlarged in fruit, usually ciliate. Corolla purple-red, campanulate, 4.5-9 mm, 5-lobed; lobes broadly ovate to oblong, 2-3.8 mm, outside hairy, occasionally glabrous, white villous. Stamens are nearly equal to corolla in length, and generally 4 in number; filaments villous. Style nearly equal to stamens in length; stigma capitate. Achenes obovoid, 3-4 mm, totally or only above white hispid, to entirely glabrous; persistent calyx with lobes deltoid to ovate, 1.5-2.5 mm, obviously reticulate veined, margin usually white hispid, apex acuminate, rarely acute. The leaves are pinnatisect, without stipules. The flower is cluster, and usually has many small flowers. They are bilaterally symmetric and usually bisexual. The calyx is located on the top of the ovary and basically four lobed. The corolla is united and having 5 lobes. Ovary three carpelate of which only one is fertile. Within Valerianaceae there is a degree of specialization in flower and fruit morphology. The most noticeable differences are in floral morphologies across the family especially in the number of stamens which varies from 1 to 5 (Eriksen *et al.* 1989).

Study of reproductive biology of jatamansi was reported for understanding pollination behavior of plant. Pollination behavior is an integral part of reproductive biology and both of them together are the key factors for determining the genetic variability of a population. Experiments related to parthenocarpy, passive autogamy, active autogamy, geitonogamy and xenogamy were reported. The month of July-August are peak time of flowering and anthesis time were reported between 7:00-11:00h. Pollen grains are dispersed from the anthers after 24h of anthesis. Stigma is of protogynous type. Fruit set recorded was 40% in passive autogamy, 70% in active autogamy, 53.33% in xenogamy and 86.67% in geitonogamy as well as open pollination experiments. Although, the species is self-pollinated, but for optimum pollination it depends on pollinators. Cross pollination has an adaptive value for species as it compensates the failure of autogamy and also maintains genetic variability in the population. The report also suggests that jatamansi improvement program may be initiated through xenogamy to increase its population size and ultimately the production (Chauhan et al. 2009).

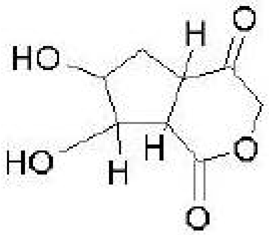
Phytochemistry

Phyto-chemical investigations have reported the presence of esters, phenolic compounds, terpenic ketone, valeranone, valeranal, nardol, calavenol, nordostechone, n-hexacosanyl arachidate, n-hexacosanol, calrene, jatamansin, β-sitosterol, iridoid (Pai et al. 1971). Terpenic ketones have 9 monoterpenes (1.7%), 25 sesquiterpenes (43.9%) and non terpenic compounds (24.7%), jatamansone semicarbazone, spirozatamole (Bagchi 1990), jatamole A and B (Bagchi et al. 1991), nardostachysin (Chatterjee et al. 2000), calarenol. Jatamansone and α-gurjunene are the major sesquiterpenic ketones isolated from rhizomes (Paudyal et al. 2012). Other sesquiterpenes isolated from oil of rhizome are nardole (10.1%), α-selinine (9.2%), γ-gurjunene (2.3%), β-caryophyllene (3.3%), cubebole (2.9%) and α-humilene (2.3%). New susqiterpene acid nardin and a new pyranocoumarin have been isolated from rhizome of jatamansi and characterized as E-2 methyl, 3-(5,9 dimethyl bicycle[4,3,0] nonen-9-yl)-2-propeonic acid and 2’, 2’-dimethyl-3-methoxy-3’,4’ dehydropyran coumarin respectively. These results were based on spectral studies and chemical co-relations (Chatterjee et al. 2005). The chemical structures of some medicinally important compounds are given in Figure 1.

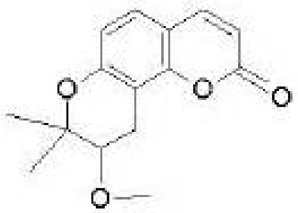
Medicinal uses

Jatamansi is known for several medicinal properties. It is most commonly used as a nervine sedative in the treatment of insomnia and also to treat chronic irritability and nervousness, with exhaustion and debility. Jatamamsi primarily acts upon the nervous system, inducing a natural sleep, without any adverse effect upon awakening, and appears to lack the stimulating effects. Rhizome of Jatamansi have also been used in traditional medicines as bitter tonic, stimulant, antipyretic, antispasmodic, antiseptic, anti-lipid peroxidative (Tripathi et al. 1996), anti-malarial (Takaya et al. 1998), anti-rhythmic, sedative (Amin et al. 1961) antidepressant (Dhingra and Goyal 2008a), diuretic, cardiac tonic, tranquilizer, laxative, stomachic, improve learning & memory

(Joshi and Parle 2006), and also shows cytotoxic property (Itokawa et al. 1993). Extract of Jatamansi is used in preparation of hair tonic, hair oils, promoting hair blackness, growth and luster (Bagchi et al. 1991). It is also used in oils and pastes that improve complexion and general health of the skin. The detailed medicinal properties are being discussed in following heads.



Jatamanin1



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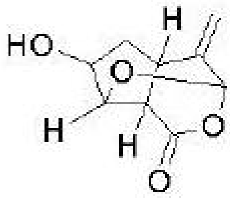

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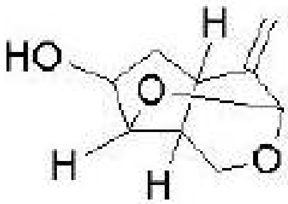
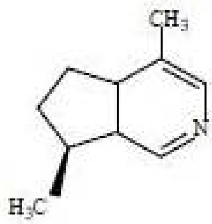
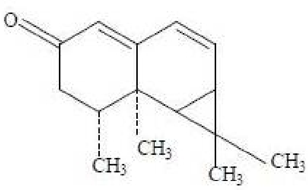


Jatamanin4



Actinidine



Nardostachone

Figure 1: Chemical structures of some important medicinal compounds.

Cardioprotective efficacy

Studies have reported the role of jatamansi extract in cardioprotective action. Doxorubicin is used to cause cardiac tissue damage especially on mitochondria and lysosome. Heart mitochondria isolated from rats treated with doxorubicin single dose, exhibited depressed rates of respiration, low respiratory control ratio (RCR), decreased Oxidative Phosphorylation ratio, Adenosine Triphosphate content and cytochromes. In addition the doxorubicin given rats showed significant changes in the lysosomal enzymes (Cathepsin-D, Acid phosphatase, BETA-D-glucoronidase, BETA-D-galactosidase and BETA-N-acetyl glucosaminidase) and membrane bound phosphatases. Also myocardial damage, as assessed by ultrastructural changes showed loss of myofibrils, mitochondrial swelling, and cytoplasmic vacuolization. Pretreatment with jatamansi ameliorated the observed abnormalities and significantly prevented the mitochondrial respiration, lysosomal integrity, membrane bound phosphatases and ultrastructural studies in doxorubicin induced rats. These reports suggested that the cardioprotective efficacy of jatamansi could be mediated possibly through its antioxidant effect as well as by the attenuation of the oxidative stress clearly demonstrated the synergistic action of both the drugs (Subhashini et al. 2006).

Antioxidant property

The antiperoxidative property of jatamansi was investigated using an iron-induced lipid peroxidation model in rat liver, quantified by thiobarbituric acid reactive substance (TBARS) content. They have observed in their study that the extract provides protection against lipid peroxidation (Tripathi et al. 1996). In another study an aqueous root extract from jatamansi was investigated for its antioxidant and anticataleptic effects in the haloperidol-induced catalepsy rat model of the disease by measuring various behavioral and biochemical parameters (Rahman et al. 2011).

Antidepressent activity

The extract of jatamansi has antidepressant activities. Rat brain treated with root extract of jatamansi showed an overall increase in the levels of central monoamines and inhibitory amino acids, including a change in the levels of serotonin, 5-hydroxyindole acetic acid, gamma-amino butyric acid, and taurine (Rahman and Muralidharan 2010). In another study Swiss young albino mice treated with extract of jatamansi produced significant antidepressant-like effect in both tail suspension and forced swim tests. The efficacy of the extract was found to be comparable to imipramine and sertraline. The extract decreased the whole brain MAO-A and MAO-B activities, thus increased the levels of monoamines. The results of study suggested that the antidepressant-like effect of the extract may also be due to interaction with GABA receptors, resulting in decrease in the levels of GABA in mouse brain (Dhingra and Goyal 2008b).

Hepatoprotective properties

The root extract of jatamansi also possess the hepatoprotective activities and it has been proved by several studies. Ethanolic extract of the jatamansi rhizomes showed hepatoprotective activity. Rats treated with the extract of jatamansi significantly ameliorated the liver damage in rats exposed to the hepatotoxic compound thioacetamide. Elevated levels of serum transaminases (aminotransferases) and alkaline phosphatases, observed in thioacetamide alone treated group of animals, were significantly lowered as in jatamansi pretreated rats. Pretreatment of the animals with the extract also resulted in an increase in survival in rats intoxicated with LD90 dose of the hepatotoxic drug. These reports significantly mentioned hepatoprotective features of jatamansi (Ali et al. 2000).

Protection from hair loss

Extract of jatamansi is also used for protection from hair loss. Ethanol extract of jatamansi was examined for hair growth on albino rats. The hair growth activity that was worked on chemotherapy induced alopecia model was investigated by using various parameters like hair density, lymphocyte count and testosterone level along with histo-pathological study. Hair growth initiation time was markedly reduced to half on treatment with extract as compared to control animal. The time required for complete hair growth was also significantly reduced (Gottumukkala et al. 2011; Yadav et al. 2011). These study reports of jatamansi as potential stimulant of hair loss.

Role in seizures

Ethanol extract of the roots of jatamansi was studied for its anticonvulsant activity and neurotoxicity, using rat as a model system. The results demonstrated a significant increase in the seizure threshold by root extract against maximal electroshock seizure (MES) model as indicated by a decrease in the extension/flexion (E/F) ratio. However, the extract was ineffective against pentylenetetrazole (PTZ)-induced seizures (Rao et al. 2005).

Anti- Parkinson activity

Parkinson's disease (PD) is one of the commonest neurodegenerative diseases, and oxidative stress has been evidenced to play a vital role in its causation. It was evaluated that ethanol extract of jatamansi can slow the neuronal injury in caused by Parkinson's in rat (Ahmad et al. 2008).In another study jatamansi roots extract were analyzed for its anti-parkinsonism activity by measuring various neurological and behavioral parameters. Haloperidol was administered in rat body in order to induce Parkinsonism. Hydro-alcoholic root extract of jatamansi reversed the haloperidol induced Parkinsonism significantly, when compared to drugs, i.e. combination of L-dopa & Carbidopa. The levels altered by haloperidol were restored significantly by the administration of hydro-alcoholic root extract of jatamansi (Rasheed et al. 2010). These reports confirm the potential role of jatamansi to protect the brain damage caused by various factors.

Antioxidant and anticataleptic effects

Root extract of jatamansi was also investigated for its antioxidant and anticataleptic property in the haloperidol-induced catalepsy rat model of the disease by measuring various behavioral and biochemical parameters. Catalepsy was induced by administration of haloperidol in male albino rats. A significant reduction in the cataleptic scores was observed in all the drug-treated groups as compared to the haloperidol-treated group; with maximum reduction observed in the jatamansi administered group. To estimate biochemical parameters: the generation of thiobarbituric acid reactive substances

(TBARS); reduced glutathione (GSH) content and glutathione-dependent enzymes; catalase; and superoxide dismutase (SOD), in the brain were assessed. Haloperidol administration increased generation of TBARS and significantly reduced GSH, which were restored to near normal level with the jatamansi treatment. Catalase and SOD levels were also increased to normal levels, have been reduced significantly by haloperidol administration. They showed that jatamansi reversed the haloperidol-induced catalepsy in rats and concluded that the antioxidant potential has contributed to the reduction in the oxidative stress and catalepsy induced by haloperidol administration (Rasheed et al. 2010).

Radioprotective activity

The effect of ethanol extract of jatamansi was studied on Swiss albino mice exposed to 6Gy whole body electron beam radiation (EBR). Survival assay was done to depict the lethal dose for EBR. The dose reduction factor (DRF) of jatamansi extract (NJE) was calculated by taking the ratio between LD50 of EBR with and without NJE treatment. The clastogenic effects of EBR were recorded by Micronucleus assay. The survival assay results showed that 10Gy is the LD50 for EBR. The calculated DRF for NJE was found to be 1.2. Treatment of mice with NJE for 15days before irradiation reduced the frequency of micronucleus formation in bone marrow cells. The results obtained in the study conclude the protective effect of NJE against the EBR induced mortality and clastogenicity (Madhu et al. 2011).

Insect repellent and antifungal activity

Insect repellant (Subedi and Shrestha 1999) and antifungal activity have also been reported against some fungal species like *Aspergillus niger, A. flavus, Colletotricum falcatum and Fusarium oxysporium* (Mishra et al. 1995; Singh et al. 2002). In another study oil of jatamansi was tested for fungicidal property. This oil was found fungicidal to one or the other molds, depending upon the concentrations (Sarbhoy et al. 1978).

Hypoglycemic and anti-hyperglycemic activity

The extract of jatamansi has been shown to have significant hypoglycemic activity. It decreases glucose level significantly in diabetic and nondiabetic rats as compared to respective control (Ghaisas et al. 2007). In that study different dose of jatamansi extract were used to for its anti-hyperglycemic activity, all doses of jatamansi extract showed significant anti-hyperglycemic activity as compared to control. In another study the hydroalcoholic extract of the roots of jatamansi, significantly decreased glucose level in normal, glucose loaded and alloxan diabetic (on day 15 and 30) rats as compared to respective control rats (Mahesh et al. 2007).

Role in nervous system

The cholinergic hypothesis of Alzheimer's disease (AD) has provided the rationale for the current pharmaco-therapy of this disease, in an attempt to reduce the cognitive decline caused by cholinergic deficits. Nevertheless, the search for potent and long-acting acetylcholinesterase (AChE) inhibitors that exert minimal side effects in AD patients is still ongoing. AChE inhibitors are currently the only approved therapy for the treatment of Alzheimer's disease; only a limited number of drugs are commercially available. Jatamansi was used for treatment of this disease from long time in Indian system. Recent *in vitro* acetylcholinesterase inhibitory activity of jatamansi extract proves this knowledge scientifically. That study reports 50% inhibition of AChE activity caused by jatamansi treatment (Mukherjee et al. 2007; Rahman et al. 2011b).

Anticonvulsant activity

Ethanol extract of the roots of jatamansi was reported earlier for its anticonvulsant activity in rats**.** Rao *et al.* in 2005 investigated the ethanol extract of the roots of jatamansi alone as well as in combination with phenytoin for its anticonvulsant activity and neurotoxicity in rats. Their result showed a decrease in the extension/flexion ratio which indicates a significant increase in the seizure threshold by jatamansi root extract against maximal electroshock seizure model and exhibited minimal neurotoxicity against rota rod test. When given in combination with 50mg/kg of jatamansi root extract, an increase in the protective index of phenytoin was recorded. This report clearly demonstrated the effect of phenytoin alone and in combination with jatamansi for their anticonvulsant activity.

Other medicinal properties/ activities

Methanolic extract of dried rhizomes of jatamansi were physiologically investigated, and they were found to exhibit relaxant effect on gastrointestinal and bronchiolar smooth muscles possibly mediated through multiple modes of action but mainly blockade of Ca^{+2} channels is presumably involved. The investigations on isolated tissue preparations revealed that crude methanol extract of jatamansi exerted non-specific relaxant effect against high K^+; phenylephrine and carbachol induced contractions possibly mediated through Ca^{+2}-channel blocking mechanisms. The crude methanol extract of the plant was also found to exert gastrointestinal muscle relaxant activity since it was shown to have demonstrated antidiarrhoeal effect against castor oil-induced diarrhoea in mice (Ahmad et al. 2008).

Conservation Efforts for this rare medicinal plant

Recent studies indicate that the biodiversity of family Valerianaceae is under threat in India (Prakash and Mehrotra 1994) although many members of which possess stimulating properties and constitute the drugs used in indigenous systems with great ethno botanical diversity. Some serious conservation efforts need to be taken to save the valuable plants. It can be conserved either through natural means (*In situ, Ex situ*) or through applying biotechnological tools.

In situ approaches

In situ approaches rely on vigilance, protection, restrictions and include moderate practices as fencing and erection of barriers, to legislative acts resulting in the establishment of 'Biosphere reserves', 'Gene sanctuaries', and 'National Parks'. They aim to allowing a threatened species to recuperate and reestablish itself in its native habitat and have been found to be very effective in cases where the threat to survival was due to disturbances caused by human Imposition of restriction on collections or a total ban on trade has proved to be very effective for plants that have trade value and whose exploitation is restricted to a particular habitat, as in the case of *Coptis teeta*, *Dioscorea deltoidea*, *Rauvolfia serpentine* etc. Moreover, declaring entire regions, having rich floral distribution, as biosphere reserves, has often saved a number of endemic plant species, which have a low tolerance for alien environment and have a inadequate regeneration & healing potential (Khoshoo 1986).

Ex-situ approaches

Heslop- Harrison (1974) observed that conservation may be achieved best in the field; the rate of diminution of some habitats is such that, for some taxa at least, *in-situ* conservation soon becomes impractical. Thus, threatened species inhabiting rapidly eroding land forms, areas prone to volcanic, seismic activity etc. quality for *ex-situ* conservation measures including botanical gardens, conservatories and modern laboratory based techniques of germplasm preservation and tissue culture.

Conservation through biotechnological tools

The ultimate aim of any conservation method is to maintain the population of that species. Biotechnology help in maintaining their population by two methods, it may be either through *In vitro* propagation or through using molecular marker.

Through *In vitro* methods

In vitro methods are used for conservation to produce large number of plants from minimum plant material. The technique has been efficiently used for the propagation of rare and endangered plants Moreover, *in vitro* technique can be suitably applied for understanding and overcoming the various bottlenecks that may be occurring in the lifecycle of a plant rendering it endangered viz., abortive embryos, low seed viability and specific germination requirements (Khoshoo 1986). Several studies have been attempted for conservation of jatamansi through *in vitro* methods. The *in vitro* morphogenesis in jatamansi has been attempted and regenerated shoots from callus derived roots. Callus cultures was maintained on Murashige and Skoog's medium containing 3.0 mg 1−1 of α-naphthaleneacetic acid and 0.25 mg 1−1 of kinetin when shifted to medium containing 0.25–1.0 mg 1−1 of indole-3-acetic acid or indole-3-butync acid showed profuse rhizogenesis. The callus-regenerated roots when transferred to medium containing 2.0–6.0 mg 1−1 of kinetin produced shoot buds. The *de novo* shoot bud regeneration took place directly either from the cortical cells or from the inner stelar region. In addition, direct, concomitant root-shoot development was also observed (Mathur 1992). Somatic embryogenesis was attempted from callus cultures of jatamansi were established using petiole explants on MS medium supplemented with 16.1 µM α-naphthaleneacetic acid and 1.16 µM kinetin. Embryogenesis in these callus cultures took place only upon sequential subculture of the callus on media having gradually decreasing auxin (16.1 to 1.34 µM NAA) and simultaneously increasing cytokinin (1.16 to 9.30 µM kinetin) concentrations over a period of 7 months. Somatic embryo to plantlet conversion took place on a medium containing 9.30 µM kinetin and 1.34 µM NAA (Mathur 1993).

Through molecular markers

Analysis of diversity of populations through molecular markers in rare and endangered species might be efficacious measurement and strategy of protecting them. The genetic diversity of a taxon has great implications for its long-term survival and continued evolution (Avise and Hamrick 1996). Therefore, knowledge levels and distribution of genetic diversity is important for designing conservation strategies for threatened and endangered species (Francisco-Ortega et al. 2000). High level of genetic diversity have been reported in the population of jatamansi using Random amplified polymorphic DNA (RAPDs) marker, collected from different region of central Himalaya (unpublished data). In this study populations clustered independently with altitude and geographical locations. The reason of higher diversity in different accessions of jatamansi might be due to reproductive isolation, entomophillous pollination, habitat changes & small population size in different location of Himalaya. Study also suggested that the observed morphological variations in different populations of jatamansi might be due to environmental influences, rather than altitude level differences. However, because the observed genetic differentiation among the population of jatamansi is high and little gene flow appears to exist among the accessions, management for conservation of genetic variability in this species is needed.

Conclusion and future directions

Conservation and sustainable use of biodiversity is the basic requirement to save the valuable plants on earth. *Nardostachys jatamansi* is one of them. As mentioned above it is a very useful plant due to several medicinal properties, but overexploitation makes plant status crucial and demands proper conservation. Several conservation efforts have been done so far but some serious efforts are needed to save the plant from extinction. Biotechnological tools such as tissue culture for mass multiplication and plant cell suspension cultures techniques to increase the biologically active secondary metabolites should be applied. Information regarding the pathway key genes and enzymes for pharmaceutically active secondary metabolites may prove beneficial to enhance the active constituent *in vitro* as well as *in vivo*.

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