Review of *Nardostachys grandiflora*: An Important Endangered Medicinal and Aromatic Plant of Western Himalaya

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Abstract

Western Himalaya has a very rich heritage of medicinal and aromatic plants. *Nardostachys grandiflora* is among the highly renowned medicinal and aromatic plants of this region. It is harvested for its rhizome, which is used to treat diseases such as heart palpitation, convulsions, epilepsy, and insomnia and also used as a source of aromatic oil that is used as incense, as a flavoring agent, and in quality perfumes. This species is on the verge of extinction due to overexploitation and habitat destruction. Due to its remote location as well as sparse population, scientific investigations on this species are sporadic and fragmentary. Trade-related information on this species is also scanty and fragmented. However, such studies are important because they provide insight into the scientific information available, even if meager, with a view to determining the gaps that need to be addressed in the future. This article tries to consolidate all the available information into a single compilation. A previous article along similar lines (G. Amatya and V. M. Sthapit, *J. Herbs Spices Med. Plants* 20:39–47, 1994) is now about two decades old and needs to be updated in the light of research conducted in the last two decades.

Nardostachys grandiflora DC (syn. *N. jatamansi, N. chinensis*), a critically endangered (Conservation Assessment and Management Plan [CAMP] 1997, Airi et al. 2000) alpine medicinal and aromatic herb, is a monotypic species of the genus *Nardostachys* (family Valerianaceae) and has been enlisted in Convention on International Trade in Endangered Species of Wild Flora and Fauna (CITES) Appendix 2 and the *Red Data Book of Indian Plants* (Nayar and Sastry 1988, Mulliken 2000). Weberling (1975) considered *Nardostachys* as the most primitive genus within Valerianaceae. This species is a perennial rhizomatous herb growing in subalpine and alpine forested areas of northwestern Himalaya, shedding all leaves during the winter only to sprout again after the snow melt. Known locally as jatamansi, balchhad, bulthe, bhutjata, mushkbala, masi, masijara, bala tagra, mansi, and pampe in various parts of India, Nepal, Pakistan, and Bhutan and as musk root or nard in English, it is distributed in Pakistan, India (Jammu and Kashmir, Himachal Pradesh, and Uttrakhand), Nepal, China, and Tibet. It is mostly found growing in steep areas; moist, rocky, undisturbed grassy slopes; or on stones on coarse, sandy loam soil on 40° to 70° slopes between 3,000 and 5,000 m asl (Chauhan and Nautiyal 2005). Regionally the species has been designated Endangered in Arunachal Pradesh, Sikkim, and Himachal Pradesh (India), Critically Endangered in Uttrakhand (India) and Kashmir Himalayas (India) (Kaul 2001), and Vulnerable in Nepal during the 2001 CAMP workshop (Bhattarai et al. 2002).

Literature Review Strategy

Published literature on the species was sourced from Internet and library sources. The Internet sources were accessed through the CERA (Consortium for e-Resources in Agriculture) portal of Dr. Y S Parmar University of Horticulture and Forestry, Solan, India (www.yspuniversity.ac.in) that provides free access to scientific journals of Francis & Taylor, Oxford University Press, Elsevier, Springer Verlag, Indian journals.com, Annual Reviews, CSIRO (Common Wealth Scientific and Industrial Research Organization), American Society of Agronomy, and so forth. Library sources such as books, journals, and newsletters were browsed to locate any available information on this species. Furthermore, several scientists who have worked on temperate medicinal plants were personally contacted to elicit any further information on this species.

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Forest Prod. J. 63(1/2):67–71.
doi:10.13073/FPJ-D-12-00092

Uses

Use of *N. grandiflora* rhizomes was first published during the 16th century in *Compendium of Materia Medica* in China (Fu 1993) and reported to be very effective in relieving pain and treating turgid chest. Its fibrous rhizomes, which have been used as incense in holy shrines since the Vedic period, yield a highly commercial essential oil known as spikenard oil that is effective in treating leprous wounds (Anonymous 1966, Thakur and Hussain 1989). In India, it is used in both the Unani and Ayurvedic systems of medicine, and it is valued for its antispasmodic properties helpful in the treatment of abnormal heart palpitations and constipation, as well as to regulate urination, menstruation, digestion, etc. (Jain 1994). Indian classical medical scriptures like *Charak samhita* and *Shushruta samhita* have prescribed smoking pellets (small balls used for smoking) containing its rhizome for cough, hiccups, and asthma. Roots and rhizomes are also used to tone up the brain and as hair and heart tonics (Chauhan 1984). In Nepal *N. grandiflora* rhizomes are used as nervine tonic, stimulants, external painkillers, an antiepileptic, and an antiseptic and also in treating hysteria, convulsions, heart palpitations, high blood pressure, fever, anxiety, insomnia, asthma, acidity, bronchial problems, and other health issues (Anonymous 1993). Rhizomes are used by *amchis* (traditional medicine practitioners trained in Tibetan medicine) for treating complaints including epilepsy, wounds, coughs, colds, and high blood pressure (Ghimire et al. 2005). In Pakistan, it is used to treat hysteria, epilepsy, neurosis, insomnia, constipation, scorpion stings, etc., and under the name *Asaroon*, its rhizomes are used in nine herbal preparations, according to the *Hamdard Pharmacopoeia* (Qarabadain-e-Hamdard), for treatment of hemiplegia (paralysis of one side of the body, usually following brain injury), Bell's palsy, Parkinson's disease, indigestion, and deafness due to age (Kazmi and Siddiqui 1953, Zaman and Khan 1970, Anonymous 1982, Khan and Zaidi 1989). It has also been reported to be used as a single ingredient to treat hypertension (Mulliken and Crofton 2008). It is also an ingredient in *Khamira Abresham Hakim Arshadwala,* which is used extensively to treat hypertension, arrhythmia, palpitation, and cardiac debility. It is also said to have been used as an aphrodisiac and to aid memory (Mulliken 2000).

Essential oil derived from *N. grandiflora* rhizomes has a pleasant, warm, heavy, sweet, woody, and spicy aroma, and its color varies by the location, maturity stage, and nature of the rhizomes (Amatya and Sthapit 1994). In Bhutan, the plant's aromatic rhizomes are mixed with material of other plant species, pounded, and used primarily to manufacture incense, which is burned during religious practices, including death ceremonies (Mulliken 2000). The demand for incense sticks made from its rhizomes is very high because it is considered the best ingredient for the production of traditional and higher-grade incense (Mulliken and Crofton 2008). In Pakistan, its essential oil is used as a flavoring agent, hair tonic to stimulate black hair growth, insect repellent, basic ingredient in quality perfumes, and in the cosmetic industry (Mulliken 2000). Incense sticks made out of *N. grandiflora* rhizomes are sold in the Middle East markets (Burbage 1981).

Due to widespread demand, irregular supply, and lack of cultivation, *N. grandiflora* rhizomes are adulterated by cheaper rhizomes of *Selinum vaginatum* and *Selinum candollei* and have been sold this way in the crude drug market for a long time (Singh et al. 2011).

Demand and Marketing

Major supplies of *N. grandiflora* come from Nepal (82% ± 5%), India (13% ± 5%), and Bhutan (5% ± 4%), and every year large quantities are being indiscriminately harvested and traded to European countries, especially France, Spain, and Germany, and also to the United States (Mulliken 2000, Olsen 2005, Mulliken and Crofton 2008). In international trade, it is mostly traded as unprocessed rhizomes, with semiprocessed products such as essential oil and marc (exhausted rhizomes after oil extraction) in smaller amounts (Mulliken 2000, Olsen 2005, Mulliken and Crofton 2008). There is also limited trade in finished products like incense and Ayurvedic medicines. Global supplies are falling gradually with increasing demand (Mulliken and Crofton 2008). India imports about 1,000 tons of its rhizomes annually from Nepal, aside from the illegal trade (Olsen 2005, Mulliken and Crofton 2008). Nard oil fetches about 12,000 to 30,000 Indian rupees (≈US$240 to US$600) per kilogram in international markets (Jhunjhunwalla 2010).

Habitat

The typical habitat preferred by plants of *N. grandiflora* is rocky outcrop, but it is also common in alpine meadows, juniper scrubs, dwarf rhododendron forest, open pine forests, and turf of glacial flats, characterized by typical monsoon precipitation (Weberling 1975, Amatya and Sthapit 1994, Ghimire et al. 2005). It grows on moist rocky and boulder surfaces, in crevices, and on dry rock surfaces (Nautiyal et al. 2003), where the soil is generally sandy or silty loam in texture, consisting of residue from metamorphic crystalline rocks and dark brown (moss-laden rocks) to dark gray or black rocks (in moist boulder habitats). The substrate soil is acidic in nature with pH between 5.22 and 6.04 and high organic carbon content (7.23% to 8.96%), especially in moist boulder habitats (Nautiyal et al. 2003). *Rhododendron anthopogon, Anophalis* spp., *Juniperus indica, Picrorhiza kurroa, Geum elatum, Dactylorhiza hatagirea, Rheum australe, Bergenia stracheyi,* and sometimes *Betula* spp. are the common associated species (Polunin and Stainton 1997, Anonymous 2007). In the beginning of October every year, all leaves turn yellow and become ready for perennation (His Majesty Government/ Nepal 1976, Polunin and Stainton 1997).

Morphology

Plants of this species are erect perennial herbs, growing to a height of 10 to 60 cm with the stem represented as a flowering spike as well as a rhizome (Figs. 1A and 1C). Its rhizomes are cylindrical, covered with a reddish brown network of fibers that represent dry sheathing leaf bases (Fig. 1C), 2.5 to 8 cm long and 0.5 to 1.5 cm broad, dark brown (externally) to reddish brown (internally), bear adventitious roots with a brittle fracture, and have a strong aromatic odor and acrid, slightly bitter taste (Amatya and Sthapit 1994, Dutta and Jain 2000, Kumar and Singh 2011). Cauline leaves are in two to three pairs and sessile, whereas radical leaves are in groups and petiolated (Amatya and Sthapit 1994). Inflorescence consists of three to seven terminal and axillary condensed cyme heads (Figs. 1A, 1B, and 1D). The flowers (Figs. 1A, 1B, and 1D) are rosy, pale pink, or purple, and flowering takes place during June to July followed by fruiting from August

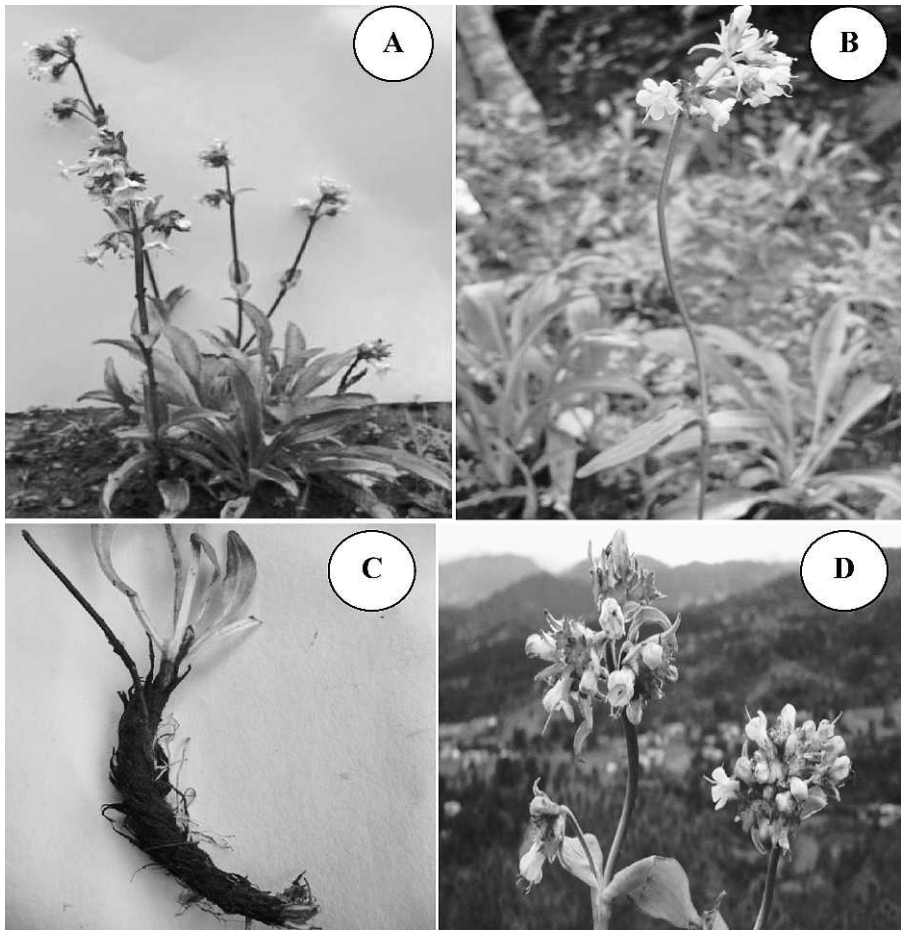

Figure 1.—Nardostachys grandiflora: *(A) plant, (B) flowering shoot, (C) rhizome, and (D) flowers.*

onward (Amatya and Sthapit 1994). Fruits are one-seeded achenes (Ghimire et al. 2005) with small white hairs and crowned by calyx teeth (Amatya and Sthapit 1994). Seed germination is very low (10% to 20%) in nature, and the plant typically multiplies vegetatively through rhizomes and its ramets, forming a dense clump (Nautiyal et al. 2003).

Plants grown from seed produce their first flowering shoot after 3 to 4 years (Chauhan et al. 2008). Flowers are hermaphrodite, gamosepalous with well-developed segments, almost actinomorphic and bell shaped (Chauhan et al. 2008). The calyx consists of five well-developed dentate lobes that are violet at the margins and green toward the center that remain persistent even after seed maturation. Petals are partially fused into a tube with five lobes (Fig. 1D), pinkish red at anthesis, turning bluish on maturation, and becoming discolored at the time of shedding. Four stamens are adnate and reach the stigma level after anthesis, with a kidney-shaped anther dehiscing longitudinally, shedding oval- to sphere-shaped pollen grains that are 50 to 60 μm in size (Chauhan et al. 2008). The ovary is inferior, bearing a single anatropous ovule with a long tube-like style. The stigma becomes receptive just prior (1 to 2 h) to anther dehiscence and is fleshy, papillose, and light violet (Chauhan et al. 2008). Honey bees, flies, ants, thrips, butterflies, etc., are common floral visitors (Chauhan et al. 2008).

Propagation

N. grandiflora can be propagated both by seeds and rhizome cuttings, with the former being reported as the best propagule (Anonymous 2008). Its seed viability is 95.00 to 98.00 percent with no intrinsic dormancy because seeds germinate within a week after shedding, under favorable conditions (Chauhan and Nautiyal 2007). Seeds treated with 100 ppm of gibberellic acid (GA_3) and rhizomes treated with 200 ppm of GA_3 for 48 hours each result in rapid germination and sprouting, respectively (Anonymous 2008). For cultivation, loamy, porous soil rich in organic matter like humus, and seed sowing at a depth of not more than 0.5 cm in soil:sand:farmyard manure (1:1:1) media during October at lower altitudes and in May at high altitudes have been found to be suitable (Chauhan and Nautiyal 2007). Replanting using part of the aboveground part along with about 2 cm of rhizome has been found to give fastest regeneration and rhizome biomass growth (Larsen 2005).

Shoot regeneration from callus as well as de novo shoot bud regeneration and direct concomitant root shoot development from cortical cells has been reported (Mathur 1992). Shoot and axillary buds from rhizome explants cultured on Murashige and Skoog (MS) medium supplemented with 0.5 mg/liter kinetin, 0.5 mg/liter benzyl amino purine, and 2 mg/liter GA_3, results in 83.33 percent bud proliferation (Kumar 2005). Somatic embryogenesis (Mathur 1993) and shoot bud regeneration (Gupta 2007) have also been reported from callus culture initiated from petiole explants.

Table 1.—Secondary metabolites of Nardostachys grandiflora.

Serial no.	Secondary metabolites	References
1	Jatamansic acid	Choudhary et al. 1951
2	Jatamansone	Govindchari et al. 1958
3	Oroseole	Mitsuhashi and Itoh 1962
4	Jatamansin, jatamansinol	Shanbhag et al. 1965
5	Nardol, calarenol, and nardostachone	Sastry et al. 1966, Pai et al. 1971, Rucker et al. 1978
6	Spriyajatamol, jatamol-A,jatamol-B	Bagchi et al. 1988, 1990, 1991
7	Nardoperoxide, isonardoperoxide, and nardoxide	Takaya et al. 1998

Chemical Constituents

Various secondary metabolites isolated from the species are presented in Table 1.

Total ash (8.5%), acid insoluble ash (3.8%), water soluble ash (0.5%), and sulfated ash (8.7%) with 7.3 percent total water soluble and 5.2 percent total alcohol soluble extractives have also been reported for its rootstock (Kumar and Singh 2011).

Clinical Trials

Clinical trials conducted on animals have confirmed anti-arrhythmic, anticonvulsant, hypotensive, and tranquilizing activity of jatamansone, a major chemical constituent of *N. grandiflora* rhizomes (Arora et al. 1962, 1985; Arora and Arora 1963). These rhizomes produced anti-Parkinson's activity in rats treated with 6-hydroxydopamine to induce parkinsonism (Ahmad et al. 2006). These rhizomes have also been found to be efficient and safe for the treatment of hypertension after conducting clinical trials on 50 patients in the age group of 30 to 70 years (Venkatachalapathy et al. 2012). Methanolic extract of its rhizomes has been found more effective than its water extract in inhibiting acetylcholinesterase activity supporting its traditional use for improving cognition (Vinutha 2007). Whole plant alcoholic extract of the *N. grandiflora* plant when mixed with alcoholic extract of *Curcuma longa* rhizomes reduced triton-induced hyperlipidemic condition in rats, thus confirming its hypolipidemic action (Dixit et al. 1998).

Genetics and Breeding System

There are only two reports of $2n = 26$ and 32 chromosomes present in this species (Goldblatt 1984, Joshi and Joshi 2001). This species has been reported as an inbreeder favoring geitonogamous pollination (87% fruit set) compared with 53.33 percent fruit set under xenogamous conditions (Chauhan et al. 2008).

Threat Perception

Realizing the high level of threat, CITES has listed *N. grandiflora* in its Appendix 2 to ensure its conservation and has banned its harvesting. It has also been listed in the *Red Data Book of Indian Plants* (Nayar and Sastry 1988). It is one of the 29 species listed in the negative list of exports of the Ministry of Commerce, Government of India, New Delhi, and among the 32 species of medicinal plants noted by the National Medicinal Plant Board, New Delhi, India (www.nmpb.nic.in) for intensive cultivation. Considering its importance and the perceived threat, there is an urgent need to domesticate *N. grandiflora* by bringing it under large-scale cultivation across suitable Himalayan locations. There is also an urgent need to extensively study its reproductive biology and to explore the chemical and morphological variation present in its remaining populations apart from further refining cultivation practices. Because the distribution pattern of the species harbors remote locations with their own climate and edaphic features that appear to influence its growth and survival, strong emphasis should be placed on prospecting the natural forests and vegetations of such regions.

Conclusions

This review summarizes all the published information on this important endangered medicinal plant species and highlights the wide gap of information that exists regarding several aspects of its biology. In order to ensure sustainable use, some of the immediate action points that need to be taken include making concerted efforts for its domestication, finding causes of low seed germination, exploring the remaining population for genetic and chemical diversity, and protecting its wild habitat before the last vestiges of this important species are lost. Apart from this, the claimed therapeutic uses also need to be clinically substantiated.

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