Seabuckthorn (*Hippophae rhamnoides* L.): Himalayan Superfruit for Sustainable Futures

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Abstract

Hippophae rhamnoides L., commonly known as seabuckthorn, is a resilient deciduous shrub native to the temperate and cold arid regions of Eurasia, including the Indian Himalayas. The plant has gained recognition for its exceptional nutritional, medicinal, and ecological value. Its berries are rich in vitamins, antioxidants, and rare omega fatty acids, while its nitrogen-fixing ability and tolerance to extreme environments make it a valuable component in agroforestry and soil conservation. Despite its potential, seabuckthorn remains underexploited in India. This review discusses the botany, distribution, ecological adaptability, propagation methods, and utilization of the plant, emphasizing its prospects for sustainable development and climate-resilient horticulture in the Himalayan region.

1. Introduction

Underutilized fruit crops in high-altitude regions offer enormous potential for nutritional security, ecological restoration, and livelihood enhancement. Among these, seabuckthorn (*Hippophae rhamnoides* L.) stands out as a versatile plant with multifaceted applications. Native to the cold deserts of Ladakh and other parts of the Indian Himalayas, seabuckthorn has traditionally been used in folk medicine and as fodder and fuel. In recent decades, its medicinal, nutritional, and commercial value has come to the forefront, prompting research and developmental interest (Stobdan et al., 2013).

Seabuckthorn is known as the "Wonder Berry of the Himalayas" due to its exceptionally high content of vitamin C, bioactive flavonoids, and unique fatty acid profiles. Beyond its health benefits, it serves as a pioneer species for revegetating degraded slopes and controlling soil erosion, making it a strategic asset in Himalayan ecosystem management.

2. Botanical Characteristics and Taxonomy

It belongs to the kingdom Plantae, order Rosales, and family Elaeagnaceae. It is a member of the genus *Hippophae*, which comprises six to seven species. Among them, *Hippophae rhamnoides* is the most widely distributed and economically significant species. Commonly known as seabuckthorn, it is a hardy shrub native to the cold arid regions of Eurasia. In the Indian Himalayan region, it is locally referred to as Chharma in Ladakh, Gurgan in Kinnaur, and Tsesta in Tibetan dialects, reflecting its cultural and ecological significance in high-altitude communities (Dwivedi et al., 2006).

Cytology, Genetics, and Ecological Adaptability

Seabuckthorn has a diploid chromosome number of 2n = 24. The species exhibits high genetic variability, especially among wild populations in the Indian Himalayas, due to diverse microclimates and altitudinal gradients (Bisht et al., 2021). This genetic diversity provides a rich base for breeding programs focused on developing improved cultivars with traits such as reduced thorniness, enhanced pulp and oil yield, and adaptability to marginal environments.

Ecologically, seabuckthorn is well adapted to high-altitude environments, thriving at elevations between 2,500 and 4,500 meters above mean sea level. It tolerates extreme temperatures ranging from –40°C to +40°C and is resistant to drought, salinity, and nutrient-poor soils (Singh et al., 2020). As a pioneer species, it readily colonizes degraded lands, glacial moraines, and scree slopes, playing a crucial role in soil stabilization, land reclamation, and carbon sequestration, making it ideal for ecological restoration in fragile mountain ecosystems.

3. Distribution and Habitat in India

In India, *Seabuckthorn* is predominantly distributed across the high-altitude regions of the western and eastern Himalayas, where its occurrence is strongly influenced by altitude, temperature, and soil type. The Union Territory of Ladakh is a major hub for seabuckthorn, particularly in areas such as Leh, Nubra Valley, and Zanskar, where it thrives along river valleys and glacial streams. The Defence Research and Development Organisation (DRDO) has spearheaded several initiatives in this region to domesticate the plant and develop local value chains in collaboration with community cooperatives (DRDO-DFRL, 2019).

In Himachal Pradesh, natural populations are found in the tribal regions of Lahaul-Spiti and Kinnaur, where the shrub grows along riverbanks and forest margins. These areas provide sandy-loam soils, intense solar radiation, and low humidity, creating optimal conditions for its growth. In Uttarakhand, seabuckthorn is found in limited but ecologically promising populations in the alpine zones of

Chamoli and Pithoragarh districts, where conservation strategies such as ex-situ propagation and community nursery establishment are being undertaken (CSIR-IHBT, 2018). Further east, in Arunachal Pradesh and Sikkim, scattered populations exist at elevations above 3,000 meters, especially in regions like Tawang and West Kameng. The species are typically found on marginal lands, degraded slopes, river terraces, and glacial moraines (Singh et al., 2014). Its remarkable resilience to limited precipitation, high wind exposure, and extreme temperature fluctuations makes seabuckthorn a keystone species for ecological restoration in fragile alpine ecosystems.

4. Ecological and Agronomic Advantages

It plays a vital role in ecological conservation and sustainable agriculture, particularly in high-altitude and cold arid regions. One of its most significant ecological attributes is its ability to fix atmospheric nitrogen through symbiotic associations with *Frankia* spp. in its root nodules, thereby improving soil fertility and enabling vegetation establishment on nutrient-poor soils (Singh et al., 2020). Its dense and fibrous root system helps in stabilizing slopes, controlling soil erosion, preventing landslides, and reducing sediment runoff into water bodies. The species also exhibits remarkable drought tolerance due to its deep-rooted structure and xerophytic leaf adaptations, allowing it to survive in cold deserts and semi-arid valleys with minimal water availability. Additionally, its robust biomass and deep rooting contribute significantly to carbon sequestration, making it valuable for climate change mitigation in fragile mountain landscapes.

From an agronomic perspective, seabuckthorn has a short juvenile period, produces high yields under suitable management, and responds well to regular pruning, which enhances canopy structure and fruit production. The plant has demonstrated excellent adaptability in silvopastoral systems, shelterbelt plantations, and agroforestry models, making it an integral species for promoting climate-resilient agriculture and ecological restoration in degraded and marginal lands of the Indian Himalayas.

5. Nutritional Composition and medicinal uses

Seabuckthorn is widely acclaimed for its rich pharmacological profile, owing to the presence of a diverse array of bioactive compounds, including flavonoids, polyphenols, vitamins (particularly C and E), unsaturated fatty acids (omega-3, -6, -7, and -9), and antioxidants. These constituents collectively contribute to its anti-inflammatory, antioxidant, antibacterial, antiviral, hepatoprotective, and cardioprotective effects (Singh et al., 2020). Seabuckthorn oil is extracted from both seeds and fruit pulp and it is particularly valued for promoting wound healing, skin regeneration, and mucosal tissue repair, making it a key ingredient in cosmeceuticals and topical formulations.

Table1. Nutritional Composition (per 100 g fresh weight)

Component	Typical Range
Vitamin C	200–1500 mg
β-Carotene (Vitamin A)	300–900 µg
Vitamin E	5–30 mg
Total Flavonoids	300–500 mg
Polyphenols	500–2000 mg
Omega Fatty Acids	6–12 g
Dietary Fiber	4–7 g
Protein	1–2 g
Calcium (Ca)	40–60 mg
Potassium (K)	300–600 mg
Iron (Fe)	2–5 mg

Traditionally, seabuckthorn has been used in Tibetan, Mongolian, and Ayurveda medicine for treating ailments such as gastric ulcers, eczema, asthma, cough, and joint inflammation. Modern pharmacological research supports these applications, with studies indicating seabuckthorn's role in managing metabolic disorders like diabetes, hyperlipidemia, and liver dysfunction. Its antioxidant potential also offers radioprotective properties, which are being explored for supporting chemotherapy and high-altitude adaptation in defense personnel (Stobdan et al., 2013). Thus, seabuckthorn stands as a potent nutraceutical and therapeutic resource, warranting further clinical exploration and value-added product development

6. Propagation and Cultivation Practices

Propagation and cultivation of seabuckthorn require carefully tailored strategies due to its dioecious nature and adaptation to harsh environments. Seed propagation is primarily used for breeding purposes and rootstock development; however, it presents challenges such as seed dormancy and genetic variability among seedlings. For maintaining elite mother lines, vegetative propagation methods such as hardwood cuttings, root suckers, and layering have proven effective (Kumar & Sharma, 2019). Additionally, micropropagation through tissue culture by using nodal segments and apical meristems is being standardized for large-scale multiplication and conservation of superior genotypes.

Cultivation is best initiated during the spring season (April to May) in temperate regions. Optimal plant spacing is recommended at 2–3 meters between rows and 1.5–2 meters between plants. Due to its dioecious nature, it is crucial to maintain a male-to-female ratio of 1:6 to 1:8 to ensure effective wind pollination. Application of farmyard manure (FYM) and a balanced NPK fertilizer regime during the

establishment phase enhances plant vigor and survival. Regular pruning is essential to maintain canopy structure, stimulate fruit-bearing branches, and facilitate harvesting. During dry periods and critical stages like flowering, drip irrigation is recommended to improve water-use efficiency and plant performance under arid or semi-arid conditions.

7. Post-Harvest Management and Value Addition

Seabuckthorn berries are highly perishable and possess a short shelf life, necessitating immediate post-harvest processing to retain their nutritional and therapeutic qualities. Harvesting remains a major challenge due to the plant's sharp thorns and dense, woody branches, making manual picking labor-intensive and time-consuming. To address this, alternative methods such as branch cutting and vibration-based tools are being explored for improving harvest efficiency. After collection, sorting and cleaning are critical steps to eliminate debris, under-ripe, and damaged berries, ensuring quality consistency for processing. Maintaining a cold chain, especially rapid refrigeration at around 4°C, is essential to prevent degradation of bioactive compounds, particularly vitamins and polyphenols, before value addition.

A wide range of value-added products are now developed from seabuckthorn, including juices, squashes, jams, herbal teas, and nutraceutical oils extracted from both seeds and pulp. The oils are extensively used in cosmeceuticals and therapeutic products such as creams and ointments for skin care, wound healing, and anti-aging formulations. Additionally, seabuckthorn is processed into dry powders, capsules, and syrups for use as dietary supplements. Institutions such as DRDO, CSIR-IHBT, and NIFTEM have made significant strides in developing processing technologies that support decentralized, small-scale seabuckthorn processing units, thereby promoting rural entrepreneurship and value chain development in Himalayan regions (DRDO-DFRL, 2019).

8. Challenges and Future Perspectives

Despite its immense potential, seabuckthorn remains largely underutilized in India, primarily due to several persistent challenges. These include the absence of commercial-scale plantations, a lack of certified nursery stock, and the laborious nature of manual harvesting, which is complicated by the presence of sharp thorns and dense branching (Singh et al., 2020). Additionally, there is limited consumer awareness and market demand, alongside inadequate research on domestication, selection, and development of elite cultivars. The remote and rugged terrain of seabuckthorn-growing areas further hampers infrastructure development, including processing and marketing facilities.

To overcome these constraints, a multi-pronged strategy is needed. Priorities should include the development of thornless, high-yielding, and monoecious cultivars suited for cultivation and mechanized harvest. Innovations in smallholder-friendly harvesting tools, as well as investment in cold chain systems and decentralized processing hubs, are essential for scaling up value chains. Branding, Geographical Indication (GI) registration, and promotion of Himalayan seabuckthorn products can help improve consumer perception and demand. Furthermore, farmer training, capacity building, and integration of seabuckthorn into agroforestry and climate-resilient agricultural policies are vital for long-term adoption. Success in these areas will require interdisciplinary collaboration among horticulturists, ecologists, food technologists, rural development experts, and policymakers to fully integrate seabuckthorn into India's high-altitude farming systems and sustainable livelihood programs.

9. Conclusion

Seabuckthorn represents a sustainable opportunity for transforming the socio-economic fabric of cold desert and high-altitude regions in India. Its nutritional richness, ecological resilience, and multipurpose utility warrant its integration into mainstream horticultural and agroforestry programs. Strategic policy support, market development, and farmer-centric interventions can unlock the true potential of this Himalayan miracle plant.

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