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Opinion Paper

# Mining Indian Cold-Desert-Gold: The Seabuckthorn for Health and Sustainable Development

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**Abstract:** The geopolitical situation warrants rapid and sustainable development in the cold desert regions of India, particularly at high-altitudes of Himalayas. However, the difficult terrain, inclement weather, extreme temperatures, low precipitation, intense solar radiation, all put together, challenge the traditional cultivation and job opportunities in such regions, thereby slowing growth and economic progress. These factors necessitate management and efficient use of natural resources through inclusive policies to strengthen the economy and promote growth. Seabuckthorn, a multipurpose dioecious shrub bearing orange- to yellow-coloured berries, has been growing abundantly in the Himalayan wilderness since the 8th century and is well adapted to the region's harsh climatic conditions. Its berries and leaves offer significant pharmacological value, aligning traditional medicinal knowledge with modern scientific validation. Across the world, Seabuckthorn is gaining increasing recognition for its remarkable economical, ecological and pharmacological potential, rightly earning it the title "Cold-Desert-Gold". Leading market research agency Stratistics MRC, forecasted Seabuckthorn global market to reach USD 890.7 million by 2030 at CGAR of 12.1%. It is noteworthy that the Indian Seabuckthorn market, though has remained nascent so far, yet demonstrates considerable potential for expansion. This paper briefly reviews the diverse uses of Seabuckthorn and opines on the gap areas for research, sustainable agricultural practices, strategic measures and policy support required to achieve multi-fold growth of Seabuckthorn-led sustainable development in Indian cold deserts.

**Key words**: *Hippophae,* cold-desert, radiation, sustainable development, health, nutrition, economic-growth.



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The cold-deserts of high-altitudes are arid, receive limited (less than 25 cm) annual precipitation often as snow or fog and experience extreme temperature variations. Rarified atmosphere intensifies the temperature extremes, causing rapid heating during the day and severe cooling at night; summers are hot, while winters are bitterly cold and long. Soil is dry, sandy or rocky with poor fertility. The ecosystem is fragile with limited

natural resources. Indian cold-desert regions of the Trans-Himalaya—comprising Ladakh (Union Territory), Lahaul–Spiti (Himachal Pradesh), and Niti, Mana, Neelong, and other parts of the Garhwal region of Uttarakhand—are predominantly located along the country's border areas. Upscaling economic growth in these parts shall bring prosperity, increase job opportunity and ease human inhabitation, which is so very essential for the security of the mainland.

Seabuckthorn (*Hippophae* L.) is an angiosperm belonging to Family *Elaeagnaceae*, Order Elaeagnales and Genus *Hippophae*.. The most common species is *Hippophae rhamnoides,* which has several sub-species like ssp *sinensis* or ssp *turkestanica.* In India *H. rhamnoides* is in abundance at Ladakh, while *H. salicifolia* is found mostly in Uttarakhand and Lahaul-Spiti. Locally known as 'Tsermang' or 'Tsetaluler', in Ladakh, Seabuckthorn is spread far and wide in three different valleys namely Nubra, Indus and Zanskar, located at a height of 3000 to 3500 m above MSL. The natural and large-scale availability of Seabuckthorn *(Hippophae* spp.) in cold-desert ecosystem for thousands of years exemplifies its ecological resilience through multiple adaptive measures including enrichment of numerous stress tolerant molecules. It is a dioecious plant with extensively developed root system and dense foliage, which contribute significantly to soil conservation as well as biodiversity preservation. Almost all plant parts of Seabuckthorn have been found useful. Berries and leaves are particularly sought-after in the health sector, due to their high content of multiple vitamins, antioxidants and essential fatty acids. The abundance of Seabuckthorn in wilderness of Ladakh is shown in Figure 1. Due to its diverse uses in food, beverages, nutraceuticals, cosmetics and pharmaceuticals, the Indian Seabuckthorn is emerging as an important source of income and livelihood. Globally, Seabuckthorn has been recognised as a major source of income for rural communities, particularly in regions where traditional cultivation is not possible. Scaling up cultivation, as well as commercialisation of Indian Seabuckthorn and related industry, promises formidable opportunities for strengthening rural economies and employment generation.

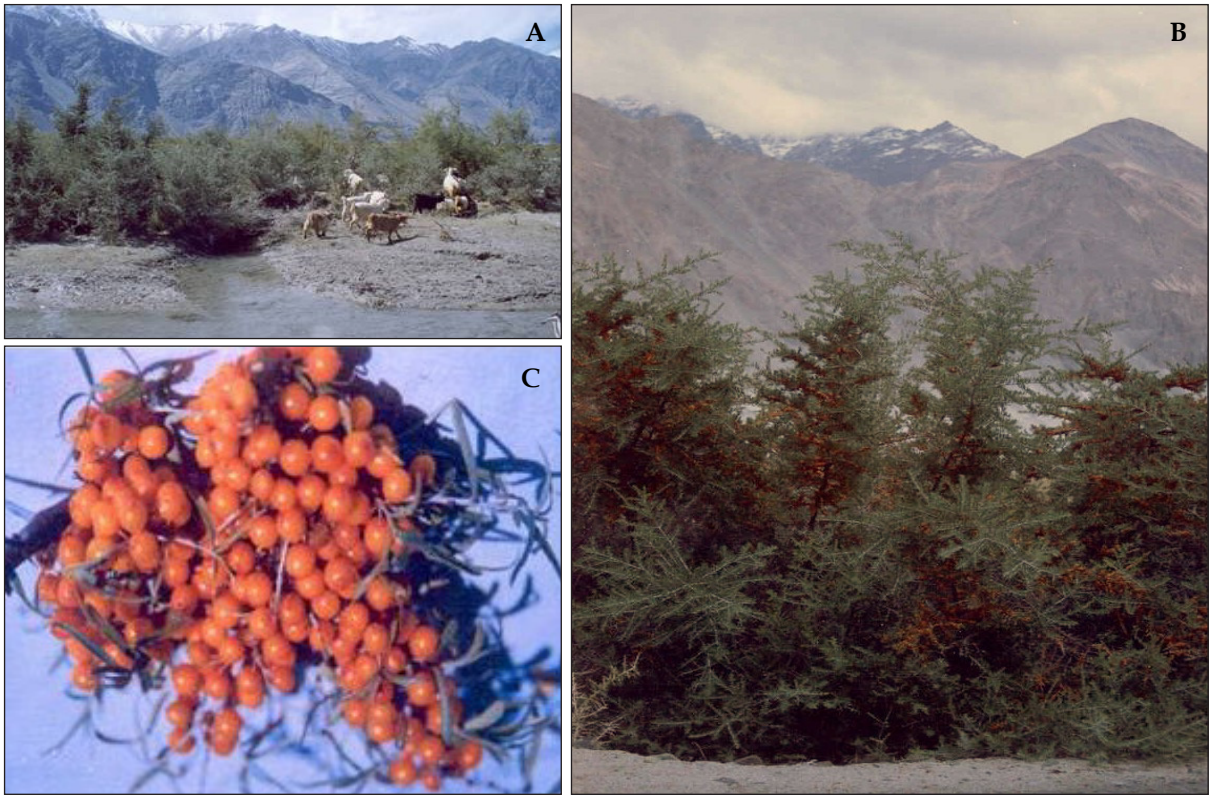


*Fig. 1. A) Hippophae rhamnoides growing in abundance in wilderness of Leh Ladakh. B) Close up view of H. rhamnoides bushes showing dense foliage and golden- crimson-coloured berries. C) The harvested berries of H. rhamnoides*

**Health Benefits**

The extraordinary benefits of Seabuckthorn in health and nutrition accrue because of its tiny yellow-orange berries as well as silvery lanceolate leaves which contain a rare combination of vitamin C, vitamin E, vitamin A, antioxidants, flavonoids, carotenoids and polyphenols, fatty acids such as omega-7 and omega-3 fatty acids. Therefore, the leaves, whole fruit, pulp, seeds, berry skin and oils have found diverse pharmacological uses across Europe and Asia for their anti-aging, anti-inflammatory, anti-cancer, anti-microbial, anti-viral properties, boosting immunity and improving skin health by treating UV burns, wounds, eczema, dryness, acne and promoting skin hydration. Traditionally Seabuckthorn has been used by the natives for aiding digestive system and relieving ulcers, supporting heart health by regulating blood pressure. Modern research continues to validate the pharmaceutical and nutraceutical uses of Seabuckthorn, positioning it as a promising candidate for developing novel therapeutic agents. The dual role of Seabuckthorn in the traditional as well as modern medicinal system, enhances its global appeal as a precious medicinal plant (Wang *et al*., 2022; Stasilowicz-Krzemien et al., 2024).

Extensive research at Defence Research and Development organisation (DRDO) has unequivocally proved the radioprotective potential of *Hippophae rhamnoides*. The medical radiation countermeasure drugs are essential components of nuclear-emergency preparedness response. Such medical agents are used for prevention treatment and clinical management of injuries caused by deeply penetrating ionising radiation, which invariably happen to the exposed populations during nuclear accidents and/or during nuclear warfare. Excellent reviews have documented that despite decades of research after World War II, few agents are approved for human use (WHO, 2023; MacVittie, 2023). More than 4000 single molecules and synthetic compounds were rejected during clinical and pre-clinical studies due to the safety issues. More recently, the preparations from medicinal plants particularly from leaves and berries of *Hippophae rhamnoides* are emerging as preferred options because they are safe (Goel and Bala 2006). Pre-clinical studies have shown that a single prophylactic dose of SBL-1, (prepared from Seabuckthorn leaves), rendered more than 90% survival benefit to populations exposed to lethal doses of deeply penetrating ionising radiation emitted by Cobalt-60-gamma-rays. The SBL-1 acted by countering radiation induced haematopoietic syndrome, gastrointestinal syndrome and brain damage (Bala *et al*., 2015, 2017). SBL-1 displayed strong anti-oxidant potential, metal chelation properties, scavenging of hydroxyl and superoxide radicals and displayed synergistic and well-orchestrated action of multiple biochemical and genetic pathways, which resulted in protection to bone marrow, jejunum, liver, spleen, renal system and restoration of gut microbiota. (Bala *et al*., 2022).

**Economical Potential**

The economic potential of Seabuckthorn is vast, its uses are promoted as functional food, beverages, jams, jellies, dietary supplements, skin care products in many parts of globe. Seabuckthorn leaves contain considerable protein content (12 to 18%) and therefore form ideal constituent for pet food and fodder. The leaves are being used as tea and are also the constituents of local wines in Tibet, China and Himalayan regions of India. Okanogan Seabuckthorn tea is very popular in Canada. In India most of Seabuckthorn products are prepared locally and contribute to income of natives (Christaki, 2012). Industrial processing of berries into juices, jams, jellies, oils and capsules offer 50-300% margins. Value addition to these products can boost the economy by creating jobs and improving livelihood opportunities. According to *Stratistics MRC*, the global seabuckthorn market was valued at USD 398.9 m in 2023 and is projected to reach USD 890.7 m by 2030, growing at a CAGR of 12.1% during the forecast period.

**Ecological Potential**

Seabuckthorn grows on rocky soils and marginal lands with poor fertility. It has been found growing along the irrigation channels and also on the banks of Indus River. It is a bushy plant, varying in size from 1 to 9 m, and grows profusely on the steep slopes of mountains as well. Singh *et al*., 2020 conducted an extensive survey of distribution of Seabuckthorn in Uttarakhand. The well spread root system of Seabuckthorn (Fig. 2), together with multiple microbial associations, particularly with

*Rhizobium* and vascular arbuscular mycorrhiza, renders a resilience ecosystem, promote water retention, soil conservation and soil improvement. Seabuckthorn, therefore, is a valuable plant for biodiversity preservation and land restoration in the fragile ecosystem of cold-deserts.

**Indian Seabuckthorn Market**

In comparison to global market the Indian Seabuckthorn market is small and is valued at around Rs. 4000 to 5000 m. The market potential spans across health drinks, premium juices, nutritional supplements and skin care products. With increasing demand for natural health products, the Seabuckthorn market is expanding and is positioned for significant growth in years to come. Currently most of Seabuckthorn is wild-harvested rather than cultivated, resulting in inconsistent supplies causing a significant hinderance to industrial growth. With support from government and setting up of a dedicated Centre of Excellence for Seabuckthorn research, awareness is being created amongst farmers for cultivation. One hectare of Seabuckthorn is expected to generate Rs. 0.5 to 0.8 myr$^{-1}$ for the farmers of cold-deserts of Ladakh, Himachal Pradesh and parts of Arunachal Pradesh.

**Gap Areas, Challenges and Possible Solutions-Indian Scenario**

Inadequate awareness amongst farmers, non-availability of early maturing and high yielding varieties and lack of organised supply chain, are some of the major obstacles to large scale commercialization. More research and development are needed at the laboratory level to develop improved varieties, which have higher yield and are early maturing. The demand for berries is high in nutraceuticals and pharma sector while foliage requirement is relatively more in the beverages sectors.

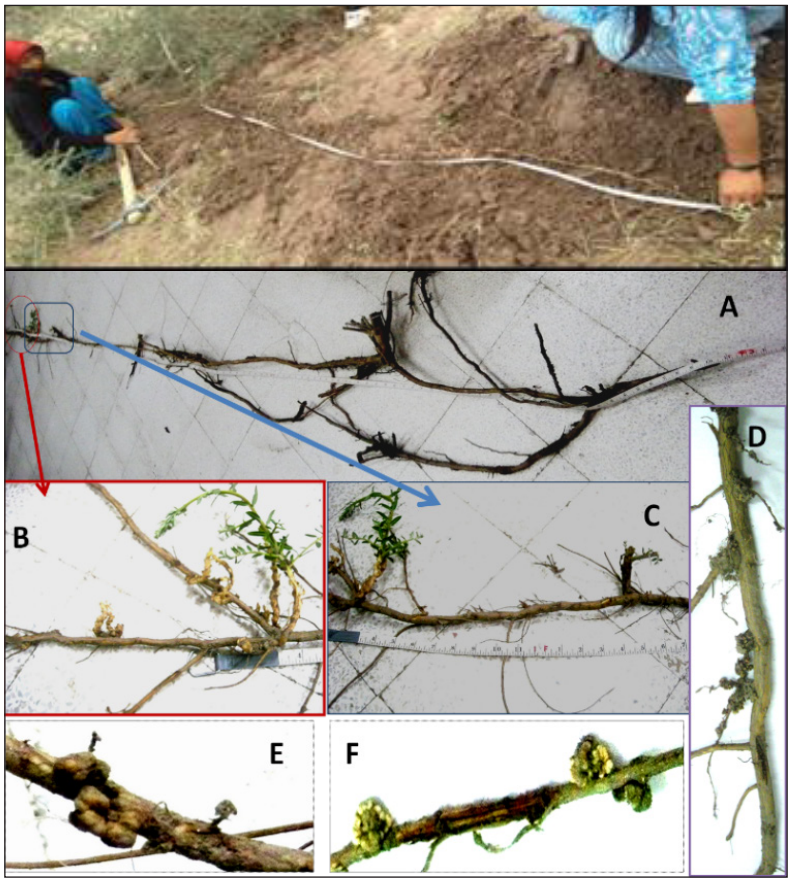


*Fig. 2. Typical view of approximately 13 feet long root of H. rhamnoides, with branches, suckers, nodules and germinal centres. A&B) Enlarged view of germinal points giving rise to new branches. C) the typical distance between the two germinal points was between 1.5-2 feet after a distance of about 3 feet from the main plant. D & E) clusters of brown nodules and the magnified view of brown nodules. F: Magnified view of some nodular structures with white bodies on the periphery, giving it white colour.*

*Fig. 3. A&B) Typical view of natives selling Seabuckthorn leaves, tea and berries in open market of Mana village, Uttarakhand. C&D) The accumulation of moisture in poly packs of semi-dried leaves reduces the shelf life.*

Identification of suitable markers for early detection of male and female plants, will be of great help to the industry. Shelf life of berries is short and is another gap area which needs attention of researchers. There is urgent need to intensify research in the crucial areas such as, comprehensive identification and standardization of bioactive biomolecules, for quality control in pharma preparations (Agnihotri, 2025). Recent studies have reported the isolation of microbial strains from seabuckthorn roots and rhizosphere soils belonging to Frankia, Bacillus, Brevibacillus, Pseudomonas, Azorhizobium, mycorrhizae, and Paenibacillus, which extracellularly produce industrially important enzymes such as pectinase, cellulase, and folic acid (Bhadrecha *et al*., 2020, 2021). Careful isolation and culturing of such microbiota from Seabuckthorn rhizosphere, together with intelligent bioprocessing can boost the textile and health-products' industry.

Cultivation challenges in cold desert regions, particularly in the Union Territory of Leh, are numerous. These include, but are not limited to, a short cultivation period (June to September), intense solar and ultraviolet radiation throughout the year, inadequate agroforestry techniques, and limitations in soil and water management. Farmers need training in careful and controlled irrigation, pest management and frost management at early stages. Research and development are essentially needed in developing comprehensive and integrated farming approaches (Yadav, 2025). India's cold deserts have diverse climates; therefore, development of region-specific agronomic techniques is much needed. *H. rhamnoides* is thorny, making harvesting very tricky. Designing and development of efficient gadgets is required to augment mechanised harvesting. Besides GI tagging, more programmes and workshops can increase the awareness amongst farmers and motivate them to undertake Seabuckthorn cultivation.

Suitable policy framework and implementation support needs to be developed to help developing organised supply chains and enhance the market growth. The public private partnership is yet another area which remains under-developed in this sector, and needs significant improvement. Post-harvest and processing technologies are essentially needed to improve the profitability. Figure 3 shows the picture of a typical market in Mana village of Uttarakhand. In the absence of adequate support from industry, the natives are forced to sell the unprocessed or semi-processed products in the open market, fetching them meagre profits and seriously compromising their livelihood opportunities. Some of the recently introduced policies by Indian Government (the production linked Incentive schemes, MSME support, Start -up India, Make-in-India) require further

customised strengthening keeping in view the difficult terrain of Seabuckthorn growing regions.

### Conclusions

The cold-desert-gold Seabuckthorn, acquires dimensions much more than a plant species. It has emerged as a symbol of resilience in fragile ecosystem supporting health as well as biodiversity. Its adaptability to arid, high altitude climate underscores it's role in soil conservation, biodiversity support and climate resilience. At the same time, Seabuckthorn berries and leaves offer significant pharmacological value, aligning traditional medicinal knowledge with modern scientific validation. To explore the multi-faceted potential of Seabuckthorn, within the context of India's cold-desert eco-system, interdisciplinary collaboration, involving ecologists, pharmacologists, farmers, economists and policymakers, is crucial. It is important to integrate the scientific innovations, advanced techniques for sustainable cultivation, harvesting, preservation and transportation, together with market development strategies. Learning can be from the established models of Seabuckthorn-agro-economy of neighbouring countries. By doing so, India can transform its cold-desert regions into hubs of sustainable development. Careful nurturing with a clear road map on policy support can lead to socio-economic transformation, benefitting not only the local communities but also positioning India as a significant player in the global Seabuckthorn Industry.

## Competing Interests

The authors declare no competing interests.

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**Madhu Bala,** M.Sc., Ph.D. (Gold Medallist) FABMS, FISRB, former Director of DIBER, DRDO Uttarakhand (2017–2022) and Addl. Director, INMAS, DRDO (2016–2017) is contributing at the intersection of Defence life science research and Applied plant sciences, spanning in areas of biological radiation protection, bioenergy, biofuels, bio-threat mitigation, and bio-resource conservation. Dr Bala's tryst with Seabuckthorn began in year 2000; and she led a team of scientists and research scholars to unravel its extraordinary potential through fundamental research, subsequently integrated it into botanical preparations for radiation protection and therapies for rare pathologies debilitating the soldiers. While at Uttarakhand, Dr Bala promoted cultivation of Seabuckthorn, championing the cause of farmers. She served as President of Indian Society for Radiation Biology (2018–2025), and Vice President of Seabuckthorn Association of India (2019–2025). The team efforts of all research scholars, technical officers and associated scientists, in Seabuckthorn studies are gratefully acknowledged.

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