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Seabuckthorn: A multipurpose shrubs species in Ladakh cold desert

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Abstract

Seabuckthorn is a perennial, woody, spinescent, dioecious, nitrogen fixing (non-leguminous), actinorhizal, wind pollinated plant. It bears yellow or orange-red berries, referred to as 'Leh berry', "Wonder berry" or "Ladakh gold". The plant is growing wild in the cold and dry regions of Indian Himalayas mainly in Ladakh (J&K), Lahaul- Spiti and Kinnaur (HP), Kumaon Garhwal (Uttarakhand) and Sikkim/Arunachal Pradesh in the North-East region. The ripe fruits of Seabuckthorn are a rich source of vitamins (A, B, C, K, and E) with antioxidant and anti-stress properties. Seabuckthorn can act as a prominent afforestation species of Cold desert due to its property of having physiological mechanisms to grow under environmental stress. The other properties which advocate the potential of Seabuckthorn as an afforestation plant in Ladakh are cold-resistance, drought-tolerance, resistance to salty and alkaline soils and resistance to strong winds. Seabuckthorn can withstand extreme temperature from -43 °C to +40 °C. It can be easily propagated through seeds and cuttings so bulk of planting material can be produced easily which acts as the primary requirement for afforestation. Seabuckthorn fix 180 kg of nitrogen/ha/year which generally improves soil fertility. SBT berry which used to get Rs. 8.0 per kg in the year 2001 is being sold for Rs. 50.0 per kg in 2016. It is estimated that the area under pure SBT is 7184 ha while the area under mixed SBT is 2083 ha in Ladakh. In Nubra valley the shrub is estimated to be growing in 2876 ha. Ladakh remains the major site for a natural SBT resource with over 70 per cent of the total area (13,000 ha) under SBT in the country.

Keywords: Seabuckthorn, Ladakh, cultivation, propagation and management

Introduction

Seabuckthorn (*Hippophae spp.* L.) is an ecologically and economically important plant that belongs to the family Elaeagnaceae. The name is from its habit of growing near the sea, and from the possession of many spines or thorns that are reminiscent of some buckthorn species⁵⁶. It has silvery deciduous leaves and colorful red, orange or yellow berries that remain on the shrub throughout the winter. The plant is hardy and it can withstand extreme temperatures from -40 °C to 40 °C. Seabuckthorn leaves are small, cuticle is thicker, crib-texture is well developed, leaf back densely covered with scales and star-hair to cover stoma. The shrub develops extensive root system having the ability to fix atmospheric nitrogen^[2, 13, 41]. It is therefore an ideal plant for soil erosion control, land reclamation, wildlife habitat enhancement, and farm stand protection in temperate regions. Seabuckthorn is mentioned in the writings of ancient Greek scholars such as Theophrastus and Dioscorides^[40]. Leaves and branches were added to fodder to induce rapid weight gain and shiny coat, and in fact, the generic name *Hippophae* is classical Latin for 'shinning horse'. In India, Seabuckthorn has received increasing attention after Defense Institute of High Altitude Research (DIHAR), a constituent institute of Defence Research and Development Organization (DRDO) has developed the technology for preparing beverage from its highly acidic fruit^[57]. The technology is well received by industrialists and ready-to-serve beverage is currently available in the Indian market under the brand name of 'Leh Berry', 'Ladakh Berry' and 'PowerBerry' etc^[2]. Interest in Seabuckthorn fruit can be judged from the fact that the price of fruit in Ladakh region has increased from Rs. 8.0/kg in 2001 to Rs. 23.0/kg in 2011 to Rs. 50.0/kg in 2016. Every part of the plant viz. fruit, leaf, twig, root and thorn has been traditionally used as medicine, nutritional supplement, fuel and fence, and therefore Seabuckthorn is popularly known as 'Wonder Plant', 'Ladakh Gold', 'Golden Bush' or 'Gold Mine'.

Recent research has supported and extended the traditional uses of the plant and several products are being produced for nutraceutical and medicinal values. Seabuckthorn has attracted international attention as a new crop opportunity^[50]. It is said to have momentous economic potential and is predicted by some as the next major health food fad. In view of the unique and valuable characteristics of Seabuckthorn, the shrub serves as a storehouse for researchers in the field of biotechnology, nutraceutical, pharmaceutical, cosmetic, environmental and other disciplines. It may serve as an example of how a lesser known shrub that grows in Himalayas can benefit the modern society through scientific research^[45]. In Ladakh region of Jammu and Kashmir State around 13000 ha area is reported under pure Seabuckthorn. Although two species viz. *Hippophae rhamnoides* and *H. tibetana* are found in this region^[56]. State Forest Department is constantly extending the area under Seabuckthorn through root suckers essentially for soil conservation. Area covering more than 70 ha was planted with Seabuckthorn in Hunder village of Nubra valley for fixing of sand dunes. Recently, plantations have been carried out in Durbuk and Nyoma villages in Changthang valley^[54]. The mean annual berry harvest from 2004 to 2015 was 213.4±83.9 MT, Currently, the demand for Seabuckthorn exceeds the supply capacity of the region. With the increasing trend in demand for Seabuckthorn, the berry harvest from available resource is expected to increase to 1509 MT in 2030 from current 361.3 MT. Plantation of Seabuckthorn on barren land by Forest Department and local community for greening and income generation is slowly gaining momentum. The vast barren land in the region can be brought under Seabuckthorn plantation²⁸. According to an estimate of the Forest Department, 2500 ha of barren land can be brought under Seabuckthorn plantation in Leh district. If cultivation is done on 2500 ha in a planned manner the projected net income from Seabuckthorn alone is estimated to be Rs 491 crore (USD 72 million) in the year 2030. Income generation will increase many-fold if value added products are also manufactured in the region^[3, 5].

Taxonomy

All the species of the genus *Hippophae* are called Seabuckthorn. Seabuckthorn belongs to the family Elaeagnaceae, which is in the major group Angiosperms

(flowering plants). Genera in Elaeagnaceae include *Elaeagnus*, *Hippophae*, *Lepargyrea* and *Shepherdia*. Number of species under *Hippophae* is still unclear^[45]. The classification of genus *Hippophae* has been modified over the years. Originally it consisted of only one species, *H. rhamnoides*, with three subspecies, *rhamnoides*, *salicifolia* and *tibetana*. However, according to the latest systematic classification of the genus *Hippophae* L., the genus comprises of seven species, and the species *H. rhamnoides* circumscribes eight subspecies viz. *sinesis* Rousi, *yunnanensis* Rousi, *turkestanica* Rousi, *mongolica* Rousi, *caucasia* Rousi, *carpatica* Rousi, *rhamnoides* Rousi and *fluviatilis* van Soest^[28]. The precise classification of the genus is still debatable due to the variations found in the Himalayas and the adjacent areas of Central Asia^[55, 41]. All species are diploid (2n = 24), wind pollinated, and dioecious, and are restricted to the Qinghai Plateau and adjacent areas, with the exception of the species *H. rhamnoides* L. that occurs widely but sporadically in Asia and Europe. *H. rhamnoides*, *H. salicifolia* and *H. tibetana* are being grown naturally in India. The seven recognized *Hippophae* species are:

1. *H. rhamnoides*
2. *H. tibetana*
3. *H. salicifolia*
4. *H. goniocarpa*
5. *H. gyantsensis*
6. *H. neurocarpa*
7. *H. litangensis*

Origin and Distribution

Seabuckthorn is native to Eurasia. The fossil pollens of this genus are well preserved in the lake sediments or deep soils and are usually used to indicate the past climatic oscillations⁵. Growing at an altitude between 60 to 5,200 m, the distribution of *Hippophae* is extremely wide throughout various geographical areas of the world. It is naturally distributed over the arid, semi-arid and high mountainous ecosystems of Asia and Europe. The plant is found in China, Russia, India, Nepal, Bhutan, Pakistan, Afghanistan, Mongolia, Kazakhstan, Hungary, Switzerland, Romania, Germany, France, Britain, Finland, Sweden and Norway^[55]. The plant has also been introduced to North America. In India, Seabuckthorn is known by various names and it is widely distributed in Ladakh region of Jammu & Kashmir and in pockets of Himachal Pradesh, Uttarakhand, Arunachal Pradesh and Sikkim^[12].

Table 1: Distribution of Seabuckthorn species in India.

Species	Ladakh	Himachal Pradesh	Uttarakhand	North east
<i>Hippophae rhamnoides</i>	Indus, Nubra, Suru & Changthang valley	Kukumsari, Lahaul, Kaza, Tabo	-	-
<i>Hippophae salicifolia</i>	-	Lahaul valley, Sanglavalley, Kinnaur	Yamunotri, Badrinath, Harhindun, Gori valley, Buddi, Dharma.	Lachen, Lanchug, Domang
<i>Hippophae tibetana</i>	Zaskar	Sangnam, Kibber, Takcha	Gomukh, Niti, Ranimani, Brtal, Nelong, Shinla, Milan.	North Sikkim

The *Hippophae goniocarpa* species grows in mountainous regions in Nepal and China on mountain slopes, river banks, flood lands and valley terraces. The growth altitude is typically between 2650 and 3700 m. The species is divided into two distinct sub-species- *litangensis*, *goniocarpa* and *litangensis* differs from the typical subspecies by the young branchlets and the lower surface of leaves^[14, 49]. The dry temperate and cold desert of the Himalayas is an ideal place for the Seabuckthorn to flourish because; Sea buckthorn is an early succession plant and has physiological mechanisms to grow under environmental stress, cold-resistant, drought-tolerant, saline-alkali resistant and resistant to strong wind

and therefore an ideal plant for maintaining the fragile ecosystem of the cold arid ecosystem (Table-1). It can withstand extreme temperature from -43 °C to +40 °C⁶.

Seabuckthorn can grow well with: 1. Forest trees 2. Horticulture crop

There is a need to encourage Seabuckthorn in different production system.

1. Crop land (Boundaries)
2. Pure stand (Seabuckthorn orchard)
3. With mixed plantation (Poplar, Salix, Robinia)

Cultivation Practices

Soil

Seabuckthorn is found growing profusely on a wide range of soil types viz. sandy, rocky, saline and ravine soils. However, soil with light physical structure, rich in minerals, with a pH near neutral (pH 6.5-7.5) is found to be better [39].

Irrigation

Seabuckthorn can tolerate drought conditions but it is a moisture sensitive plant especially in the spring at flowering and fruit development stage. For economic reasons. Seabuckthorn orchard establishment should be restricted to areas receiving a minimum of 400 mm annual precipitation, unless irrigated [17].

Propagation

Seabuckthorn can be propagated by various methods. Freshly harvested seeds have a short physiological dormancy and thus do not germinate immediately after harvesting and it remain viable for more than two years. Seed stratification for 20-25 days in alternate layers of moist sand yield over 85 percent germination. In Ladakh conditions, direct sowing of seeds in November also results in high germination percentage. Cold water soaking of seeds for 6 days yields 93.33 percent germination and 73.33 percent survival rate [43]. Treatment of seed with thiourea (100 mM) for 24 h has been reported to have highest germination percentage in case of *H. salicifolia*. Hard wood cutting is a method of choice for large scale propagation. One or two year old pencil thickness cuttings dipped 2/3 to 1/2 of lower portion in water for 2-3 days followed by 500 ppm IBA treatment results in 85 percent success in Ladakh condition. Planting of the Seabuckthorn cuttings in greenhouses, trenches and poly-houses result in even higher success rate in cold desert conditions [23].

Grafting

Grafting has been successfully demonstrated in Seabuckthorn. Scions treated with Heteroauxin gives better result in comparison with untreated scions [33]. Cuttings can be prepared during autumn and stored at low temperature or under snow. Scion can also be prepared during early spring. Grafting is done on one-year-old branch.

Orchard Establishment

Single or double hedge row system is recommended for Seabuckthorn plantation under orchard system. In single hedge row system the spacing between row to row is maintained at 2-4 m for pure cultivation and at 4-5 m for intercropping⁶. The plants are planted into row at a distance of 1- 2 m. Spacing is an important factor determining fruit yield.

Pruning

Moderate pruning increases the yield and reduces fluctuation of fruiting from year to year. The crown should be pruned annually to remove overlapping branches and long branches should be headed to encourage development of lateral shoots [56]. Pruning has to be done every year, since the tree becomes older and fruiting zone moves upwards to gain umbrella shape, which needs to be avoided. Mature, fruiting plants should be pruned to allow more light penetration. Just before sprouting of Seabuckthorn during spring i.e. March is the best month for pruning of in Ladakh [22, 51]. Pruning should not be done once the plant starts sprouting and autumn pruning is not advisable under the Ladakh conditions due to ultra-low temperatures and prolonged winters [6].

Fruit Harvesting

Harvesting of fruit starts soon after ripening. Fruit harvesting is the most time consuming operation in growing Seabuckthorn. The relatively small fruit size, short pedicel, force required to pull off each fruit, density of fruit on the branch and the thorniness of the plant are the major factors affecting harvesting [39]. Harvesting of fruit is comparatively easier in the early morning hours. Fruits can be harvested by various direct and indirect harvesting techniques [11, 15].

Yield

Fruit yield depends on species, cultivar, age of plantation and cultural practices. Vegetatively propagated plants starts bearing fruits at the age of 4 years while that of seedling raised plants takes 5-6 years [31]. Fruit yield under orchard system yield 10-15 t/ha. Seabuckthorn cultivar Chuisakaya is reported to yield 26.2 t/ha when planted at a spacing of 3.0 × 0.8 m in Russia. Under Ladakh condition, where the plants are growing under natural condition without any management practices, the fruit yield varies from 0.2 to 8 kg per plant. Leaf yield also depends on a number of factors. Leaf yield of 5 years old nine Russian varieties ranges from 1.0 to 2.4 kg per tree [13].

Insect, Pests and Diseases

Very few insect, pests and diseases have been reported in Seabuckthorn. Green aphid (*Capithophorus hippophae*) is reported to be the most damaging insect in Seabuckthorn. These aphids cover the lower side of the leaves and suck the cell sap thereby leaves become yellow and die. Aphids can be controlled with insecticide or by biocontrol agents such as Ladybug [14, 36]. Few diseases in Seabuckthorn have been reported and the most serious one is scab, which strikes the female as well as male plants, especially in a rainy spring-summer period [16]. Scab appears in the form of dark-brown tuberous spots, which gradually become black and glistening [18]. The spots appear either on the leaves or on the fruits.

Postharvest handling and storage

Seabuckthorn fruits are small, soft, delicate and juicy. It is highly perishable and cannot be transported over long distance. Seabuckthorn berries when overripe carry a strong musky odor with rancid taste, which can be detectable even in the fields [29]. Therefore, berry must be harvested at the correct stage, quickly transported to the processing plant, and it should be cooled immediately to 4-6 °C to retard spoilage. If the berries are to be stored for more than a few days, they should be frozen, preferably by quick freezing techniques. Pulp can be stored using preservatives such as KMS or benzoic acid [33].

Oil Extraction

Seabuckthorn contains pulp oil as well as seed oil. Pulp oil can be separated by centrifugal force or using organic solvent such as hexane [31]. Since Seabuckthorn oil is mostly used in cosmetic industry or as nutraceutical supplement, newer techniques such as supercritical carbon dioxide extraction under high pressure are preferred [4, 20].

Traditional Uses & Socio-Economic Benefits

Seabuckthorn has been judiciously used by people living in the cold deserts of Ladakh. Due to scarcity of resources, Seabuckthorn has been used traditionally for a variety of purposes [29]. Every part of the plant viz. fruit, leaf, twig, root and thorns has been traditionally used as medicine, nutritional

supplement, fuel and fence. The agricultural fields are valued the most in the region due to limited cultivable land¹⁰. Traditionally the dense and thorny shrub is planted around agricultural field and plantation sites to protect against stray animals and pedestrian movement^[28]. The dried twigs and branches are also put along the boundary walls of residential houses and fields. Plantation of timber trees like willow and poplar is an important activity in cold desert of Ladakh^[28]. The cuttings during its initial years need utmost care especially of the stray animals. To prevent animals from damaging the plants, Seabuckthorn branches are tied around the cuttings to serve as tree guard^[27]. This practice is effective in increasing survivability percentage of the plants during early stages. Cold deserts are characterized by a high wind velocity leading to environmental degradation. Windbreaks made of Seabuckthorn are effective at preventing wind erosion in open areas^[11]. The shrub can resist drying effect and physical injuries caused by the wind. The extensive root system of the shrub is ideal for soil binding^[26]. Due to extensive root system, Seabuckthorn plantation is being done around the water channel to check erosion due to water flow¹⁹. Cold deserts have a typical problem of firewood^[21]. On one hand, the region is cold and thus requires fuel wood to keep the houses warm during winter months. However, at the same time due to meager forest cover, availability of wood for firewood purpose is a major challenge^[5]. Under such circumstances, Seabuckthorn stem and branches are being used as firewood. The calorific value of dry Seabuckthorn is 4,785.5 calories per kg^[32]. The shrub is fast growing and can be stumped after every 3-5 years. Since the shrub grows fast and tolerates repeated cuttings, it reduces the harvesting pressure on other native woody plant species such as poplar, willow and juniper. Six-year old Seabuckthorn plantation on one hectare can produce 18 tons of firewood which is equal to nearly 12.6 tons of standard coal^[29]. The firewood is popular especially in monasteries and during ceremonies where the requirement of high calorific firewood is required. Most monasteries maintain its own Seabuckthorn growing areas to ensure regular supply of firewood. Seabuckthorn thus proved to be a popular green plant in the region. Charcoal that remains after burning Seabuckthorn is being used by blacksmith. Seabuckthorn stem is hard and often used as handle for agricultural implements^[10].

Socio-Economic Benefits

Seabuckthorn has immense untapped potential which can change the livelihood of the local population. As most Seabuckthorn products are derived from natural forest and community land where application of chemical fertilizers and pesticides is not practiced, the products can be certified as organic^[13]. Efforts are made to certify Seabuckthorn as organic in Ladakh region.

Ecological Impact

Seabuckthorn brings many environmental benefits, including soil and water conservation, desertification control, land reclamation, erosion and water loss control, reforestation, and the establishment of wild life habitats especially in fragile ecosystem due to its extensive root system coupled with efficient nitrogen fixation^[18]. The shrub has been found growing well in sandy, rocky, saline and ravine soils^[25, 52]. Since it is resistant to drought and tolerates soil salinity and low temperatures, it is suitable for many situations that are simply too demanding for most plants. Thorny and bushy growth of Seabuckthorn provides a protective shelter for flora and fauna thereby maintaining the fragile ecosystem^[32].

1. Nitrogen Fixation

Root nodules of Seabuckthorn have a symbiotic association with bacterium belonging to the genus Frankia having the ability to fix nitrogen in non-leguminous woody plant species including Seabuckthorn. It has been found that Seabuckthorn can fix upto 180 kg of nitrogen per ha per year, which generally improves soil fertility^[30].

2. Desertification Control

Seabuckthorn is an ideal plant for desertification control. The plant has been used successfully in Jianping County, Loess Plateau and Inner Mongolia of China, Jianping County has witnessed frequent disasters such as flood, drought, and storm as a result of indiscriminate logging leading to only 1.9% forest coverage^[23, 24]. However, plantation of Seabuckthorn on more than 67,000 hectares of land has resulted in creation of the largest Seabuckthorn forest in the world^[34, 39, 46].

3. Soil and Moisture Conservation

Seabuckthorn develops extensive root system. In 10-12 year old shrub, the horizontal root extends up to 537 cm and vertically up to 127 cm deep thus making it an ideal plant for soil binding. Seabuckthorn plantation intercepts precipitation by lush crown layer which redistribute precipitation and control surface runoff. Plantation is done along the water channel to check soil erosion¹. Plantation of Seabuckthorn improves soil physical characteristics and fertility thereby improves soil water holding capacity^[53]. It has been observed that soil moisture in Seabuckthorn plantation areas is 3-4% higher than outside the forest^[31, 19, 42]. Similarly air humidity is 10-20% higher in Seabuckthorn forest^[39].

4. Fencing and Windbreaks

Seabuckthorn is widely used for fencing around the house. Windbreaks made up of Seabuckthorn are effective at preventing wind erosion in open areas. Plants that serve as windbreaks must be resistant to the drying effects and physical injuries caused by wind, and Seabuckthorn is well suited to this task^[3, 22].

5. Firewood

Cold desert is characterized by sparse vegetation and severe cold winter. This demands growing of fast growing plant species to be used as firewood for heating houses and domestic cooking. Seabuckthorn has proved to be a popular green energy plant because of its quality biomass. In a six-year old Seabuckthorn forest, each hectare can produce 18 tons of firewood, equal to nearly 12.6 tons of standard coal²⁹. In monasteries, where hundreds of monks reside, the plant species is used as firewood to cook food^[21]. Since the shrub grows fast, it reduces the harvesting pressure on native woody plants thereby maintaining the fragile ecosystem^[18, 25, 38, 41].

6. Wild Life Habitats

It has been observed that a number of wildlife species depend on Seabuckthorn stems, leaves, flowers, roots, fruit, and seed^[20]. In the Loess Plateau of China, 51 bird species are entirely dependent and 80 bird species are relatively dependent on Seabuckthorn for their food. Seabuckthorn berries remain on the bushes all winter, unlike most fruit that fall off the plant at maturity^[55, 28]. In winter, the importance of Seabuckthorn increases as it is almost the only food available for birds. In cold arid region of Ladakh, the endangered double humped camel, yak, sheep, goat etc, survive on the plant mainly during winter months when no other fodder is available in the

region⁶. Seabuckthorn thus provides long-term benefits in terms of maintaining the ecological equilibrium and improving the environment^[38, 48].

7. Improvement of Microclimate

Seabuckthorn interacts with its surroundings just like any other plant species. Plantation of Seabuckthorn improves microclimate to a great extent within a given space and distance¹⁹. Seabuckthorn canopy influence solar radiation, air temperature, soil temperature, humidity and wind velocity⁸. The root system and the biomass improve physical properties and nutrient status of soil. Change in microclimate due to Seabuckthorn plantation depends on geography, climate, scale of plantation and on many other factors^[4, 9, 16].

Seabuckthorn Based Products

Nutritional and bioactive substances in Seabuckthorn berries and leaves have attracted the interest of researchers to develop products for preventive and curative purposes. Numerous products are made from Seabuckthorn fruit and leaves. A wide array of products is possible from Seabuckthorn for nutraceutical, cosmetic and medicinal purpose^[44, 35]. Defence Institute of High Altitude Research (DIHAR) has been working on Seabuckthorn since early nineties and has developed various Seabuckthorn based products. Some of the products such as beverage and herbal tea are very popular in Indian market^[18].

1. Beverage

DIHAR, Leh has developed a process for preparation of beverage from the highly acidic berries. The patented process has been transferred to several commercial firms, local entrepreneur and NGOs in India. The beverage is commercially available in Indian market under the brand name 'Leh Berry', 'Ladakh Berry', 'Power Berry' 'Sindhu Berry' etc. Due to preventive and curative properties of the berries, it is included in the special ration of Indian army deployed at high altitude^[17]. It does not contain any added colouring and flavoring agent. The beverage has found wide acceptance among consumers in terms of colour, taste, flavour and overall quality^[11, 16, 18].

2. Jam

DIHAR has also developed and patented Seabuckthorn jam, which is rich in vitamins and minerals. Potassium, sodium, calcium and magnesium are the major mineral element present in the product. Other mineral elements include iron, phosphorus, zinc, copper and selenium^[30].

3. Pickle

Semi-ripe berries have been used for preparing pickle. Taste and flavor are good when spices such as red chilli powder, cinnamon, cumin, cardamom, black pepper powder and clovers are added^[6]. However, hard seed inside the berry is a major problem in consumer acceptance^[24].

4. Herbal tea

DIHAR has formulated and patented herbal tea with Seabuckthorn leaves as the major constituents. Tender and healthy leaves from male plant is mixed with other high altitude herbs like salam panja (*Dactylorhiza hatigeria*), local tea (*Bidens pilosa*), local caraway (*Carum carvi*), black caraway (*Bunium persicum*), oregano (*Origanum vulgare*), local mint (*Mentha longifolia*), yarrow (*Achillea sp.*) and rose root (*Rhodiola sp.*) etc. The tea is rich in flavonoides,

vitamins and has medicinal values^[38, 29]. The technology has been transferred to commercial firms and is available in Indian market under trade name 'Si-beri'.

5. Antioxidant herbal supplement

Recently an 'Antioxidant herbal food supplement' based on Seabuckthorn and other fruit pulp has been developed by DIHAR (DRDO)^[16]. The detailed nutritional profiling of herbal antioxidant supplement has been conducted and is found rich in Vit 'C' (124mg/100gm), Vit 'A' (121 IU/100ml), Vit. 'B' complex, Vit 'E', minerals, unsaturated fatty acids etc. Acute and sub-acute oral toxicity of the product have been carried out and no toxicity is found^[7, 8].

6. Herbal appetizer

Loss of appetite and indigestion are one of the most common problems in high altitude conditions due to low oxygen pressure, unbalance nutritional diet, harsh climatic conditions, etc. Herbal appetizer has been formulated from a standardized proportion of different plants parts using *Achillea millefolium* (Yarrow), *Carum carvi* (Caraway), *Capparis spinosa* (Caper bush), *Foeniculum vulgare*, *Hippophae rhamnoides* (Seabuckthorn), *Medicago sativa* (Alfalfa), *Mentha longifolia* (Wild mint), *Origanum vulgare* (Origano), *Prunus armeniaca* (Apricot), *Rheum webbianum* (Rhubarb) and *Saussurea lappa* (Costus)^[28, 37, 47].

7. UV protective oil

A patented process for preparing UV-protective oil using Seabuckthorn oil is developed^[12]. The protective oil has been formulated from a standardized proportion of oil extracted from *Hippophae rhamnoides*, *Prunus armeniaca* and *Seasamea indicum* along with other high altitude medicinal plants containing UV protective metabolites. The oil has topical antioxidant, UV reflective, skin nourishing and moisturizing properties which protects the skin against harmful UV radiations^[14, 15].

8. Animal feed

Seabuckthorn leaves and pomace have been used to develop balance animal feed. Animal trials on lambs in Ladakh condition has showed that feeding Seabuckthorn-based feed has no adverse effects on performance and blood biochemical status of lambs. Further, it reduced cost of feed^[69].

Conclusion and Future Prospects

Seabuckthorn is a unique and valuable crop for cold arid region. It has potential to play a crucial role in the sustainable development of cold arid fragile areas. This shrub is the best example of how an ancient cultural heritage brings benefit to modern society through scientific research. The fruit and seed are the main source of its nutritional and medicinal values. These beneficial effects have made Seabuckthorn products, especially its oil, desirable for medicinal and cosmetics purposes. Beverage made from Seabuckthorn fruit is popular in Indian market and other products like tea, jam, sauce, wine, vinegar, soap, shampoo etc. are gaining popularity. The cultivation of Seabuckthorn has brought considerable social benefits. In India, the shrub grows in wild and there is immense potential for growing it in orchard system. Products made from Seabuckthorn are still few in number in Indian market and this can be increased substantially. Seabuckthorn has become a vital source for research and development work due to the presence of more than 300 bioactive agents. There is a need for novel techniques and approaches for integrated

processing of Seabuckthorn berries into their nutraceutical and therapeutic products. Similarly, berry oil has shown good potential towards platelet aggregation and beneficial effects on blood clotting in human, the further studies on dose response effect are needed to assess the practical use of berry oil supplements. There is no doubt that the future holds great promise for Seabuckthorn. This ancient plant with its powerful and healing synergies has much to contribute to this planet and its inhabitants. In arid and semiarid regions, Seabuckthorn has the outstanding capacity to improve the environment and economic development. We can look forward to a continued revelation of Seabuckthorn's many gifts through the increasing interest and research into its abundant and valuable properties. Judicious exploitation and utilization of Seabuckthorn resources can bring more benefit to mankind throughout the world. The unique characteristics of Seabuckthorn in improving the fragile ecosystem and socio-economic upliftment of the rural cold desert region are receiving attention from environmentalists and the Government. Recently, in India several mega projects on Seabuckthorn have been initiated by several R&D organizations in view of its unique biotechnological, nutraceuticals, pharmaceutical and socio-economic potential. The unique and valuable characteristics of Seabuckthorn shrub serve as a storehouse for researchers in the field of biotechnology, nutraceutical, pharmaceutical, cosmetic and environmental sciences. Traditional usage coupled with commercial value and modern scientific research brings immense benefit to modern society from the lesser known shrub of the Himalayas. It may serve as an example of how a lesser known shrub that grows in the Himalayas can benefit the modern society through scientific research.

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