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SEABUCKTHORN

A Multipurpose Plant Species for Fragile Mountains

Lu Rongsen

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Foreword

ICIMOD, with its geographical mandate extending to countries of the Hindu Kush-Himalayan (HKH) Region, attempts to facilitate ecologically and economically sound development of mountain areas. The centre carries out its mandate through problem-oriented applied research, focussed training, organised exchange, and dissemination of information relevant to mountain development. One focussed activity of ICIMOD in its current phase of work is to identify successful development experiences in mountain regions, to examine the preconditions of their success, and to facilitate replication of such success in other parts of the HKH Region. These success stories cover technological innovations, institutional initiatives, and resource management systems.

One such successful experience is the development and harnessing of the vast potential of seabuckthorn (*Hippophae L.*). This shrub-tree is widely distributed throughout the temperate zones of Asia and Europe and in the subtropical zones of Asia at higher altitudes.

China, through systematic research, has succeeded in utilising and managing wild stands of seabuckthorn and in cultivating them in well-managed, commercial plantations. The Chinese have not only rehabilitated fragile slopes using this soil-building and soil-binding plant but have also used it to manufacture several products of high value.

This paper, besides introducing the plant, summarises the Chinese experience in utilising and cultivating seabuckthorn, which is of relevance to other similar areas in the Hindu Kush-Himalayas where economically viable alternatives are very limited. In this context, it should be pointed that, besides seabuckthorn, there are many more underutilised plant species of potential value about which our present knowledge base is extremely poor. The need for a systematic search for these genetic resources and their underlying ethnobotanical characteristics and their development in an economically and environmentally sound manner will be an important step towards the promotion of biodiversity across these mountain areas. ICIMOD will continue to support this search and build up the knowledge base on underutilised plant resources of mountain areas.

The purpose of this paper is to disseminate the Chinese experience to other parts of the HKH. The paper is complemented by a 20 minute video film that helps generate awareness about the high income potential source for high mountains where not many options with high payoffs exist. Some sensitisation among mountain development agencies has already taken place through the above film and through circulation of the preliminary draft of this paper. Some explanatory work and training activities involving seabuckthorn have also been initiated. These activities are being undertaken as a part of the work under the Mountain Farming Systems' (MFS) Programme of ICIMOD. Professor Lu Rongsen, who has had more than a decade's work experience on seabuckthorn, deserves to be congratulated for this piece of work.

E. F. Tacke
Director General

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I. Introduction

Background

Mountain areas throughout the developing countries share broadly common characteristics in terms of rapid population growth, accelerated degradation of the environment and natural resource base, unsustainability of the current resource use patterns, and deterioration in economic conditions. The Hindu Kush-Himalayan (HKH) Mountains, the Qinghai Plateau, the Tibetan Plateau, and the Loess Plateau constitute a large contiguous region in Asia where poverty persists and where the resource base continues to erode at an alarming rate. According to the classification of the United Nations, among the eight HKH countries, five, namely Afghanistan, Nepal, Bhutan, Bangladesh, and Myanmar are designated as least developed countries, whereas the remaining three, China, India, and Pakistan, are low income countries, although their mountain areas are, however, in the "least developed" category. Concomitant with this spectrum of poverty and a degraded resource base is the plight of mountain people, especially remote mountain people. Their productivity is amongst the lowest and their quality of life amongst the poorest in the world.

More and more mountain areas of the HKH show distinct signs of unsustainability, decreasing soil fertility, and a high degree of instability. There is a trend of abandoning agricultural land, and this sharply contrasts with the decrease of land/man ratio in cultivated areas. This applies in particular to areas with steep topography and fragile slopes located in monsoon-affected regions with high rainfall intensity. Steep and fragile slopes are being increasingly cultivated and no longer kept under the protection of forest cover; this leads to landslides and large-scale loss of soil. The reduced flexibility and diversity of agriculture (i.e., complex of land-based activities) and resource regenerative processes, that helped to sustain natural resource use systems in a low demand situation, are other visible manifestations of the emerging scenario in most parts of the HKH Region (Jodha et al. 1992).

The rapid population growth increased the density of population on limited productive land. The necessity of meeting increasing food, fuelwood, and fodder requirements, on the one hand, and demands generated by market forces and public interventions, on the other, are the most important factors which affect agriculture in the mountains and accelerate the process of resource extraction both in forests and on farmlands. The decades of emphasis on food production without appropriate land improvement techniques have now resulted in soil erosion which has become a major environmental problem (Jodha et al. 1992).

Reconciling Extensive and Intensive Land Uses

In the past, soil erosion control through terracing, clearing of boulders, and planting trees has been the response of farmers and development agencies to the problems outlined above, but, in many cases, this response is no longer possible or workable, neither economically nor environmentally.

Currently, many areas under cultivation cannot be terraced because either the slopes are too steep or the available topsoil layer is inadequate. Terraces have been established in most areas where this is feasible. However, the terraces made on many steep slopes that are located in unsuitable areas often collapse because of heavy rainfall or because the construction of the terraces is not firm enough. The nutrient contents and soil fertility under such conditions are very low and will decline further, which in turn results in low productivity per unit area. In addition, in some remote areas terracing is very expensive, both financially and in terms of labour, and farmers cannot afford it.

One obvious solution, under such conditions, would be to de-intensify appropriate species and put the steep slopes back under forests. However, this solution is not acceptable, either on economic or on social grounds, since a large (and increasing) number of people in the hills and mountains have to depend directly upon these lands for their livelihood. Thus the key question of reconciling long-term environmental and resource conservation issues with the short-term survival strategies of mountain people is a major

challenge for the policy- makers and development agencies engaged in mountain areas.

The past efforts in practically all countries of the HKH Region have emphasised reforestation as a key component of resource conservation protection strategies. However, the efforts have met with only mixed success. The reasons for the failures are not difficult to find. While these initiatives fully recognised natural convergence between attributes of trees or forests, i.e., their resource-conserving effects, and imperatives of fragility characterising steep slopes, i.e., need for low intensity land use patterns, they did not examine the resource-intensive, high productivity, quick pay-off dimensions which could have made the resource-extensive system readily acceptable to the people to meet their short-term needs.

This calls for focussing on multiple, goal-centred strategies for resource conservation and rehabilitation. An important component of such strategies would be a choice of species that can simultaneously satisfy the long-term conservation needs as well as the short-term economic needs of the people depending upon rapidly degrading mountain resources.

Seabuckthorn is one such species that has great potential for satisfying the above requirements. The total distribution of seabuckthorn in three of the main producing countries, namely, China, Mongolia, and the former USSR is approximately 810,000 ha (natural growth) and 300,000 ha (plantation). Out of the total, approximately 740,000 ha and 300,000 ha of natural and cultivated plants respectively are in China (Koykov 1985, Huang Quan et al. 1990, Lu Rongsen 1991). However, outside China, seabuckthorn is hardly used or cultivated in the HKH Region. This paper, using experiences and evidence from China, discusses both the technical and economic aspects of seabuckthorn and indicates its prospects in different countries of the HKH Region.

Why Seabuckthorn ?

Usually, in order to control the loss of water and soil, engineering and biological measures are adopted hand in hand. Amongst the biological measures, a number of trees, shrubs, and grasses are commonly used. Since the 1950s, Chinese scientists, technicians, and farmers have been trying out many plant species. Some of them are very successful and have been used in different ecological areas. For example, Chinese Pine (*Pinus tabulaeformis*), Poplar (*Populus spp*), and Elm (*Ulmus spp*) are tree species which grow fast, can resist relatively arid weather, and can be used for timber. False Indigo *(Amorpha fruticosa)*, Pea Shrub (*Canagana korshinskii)*, Sweet Vetch (*Hedysarum scoparium*), Mongolian Sweet Vetch (*Hedysarum mongolicum*), and Sand Willow (*Salicheilophila*) are excellent shrubs that grow fast, can resist drought, cold, and wind, and can quickly occupy the ground surface so as to protect the soil from erosion. In addition, they can provide large amounts of leaves for animal fodder. Some of them even have the ability to fix nitrogen. Erect Milk Vetch (*Astragalus adsurgens*) is a perennial grass which can also resist cold, drought, wind, and sandstorms and can also grow on lean alkaline and saline soils.

Beyond a doubt, these species have played a very important role in the biological measures of water and soil conservation. In the 1970s, some species were even planted on a large scale by air-seeding on the Loess Plateau. But these successful experiences could not be adopted in other places without government persuasion and subsidies; most farmers were not willing to adopt the experiences because they did not get direct economic benefits from planting these plants. The farmers said "*If the Government gives the money, we will plant the trees*". That is the main reason why these successful experiences did not gain widespread popularity.

When information relating to seabuckthorn use in the Soviet Union reached China at the beginning of the 1980s, scientists, enterprises, and government officers were surprised to hear of its rich nutrients and useful medical properties. They became aware of its tremendous economic as well as ecological benefits. Then a great upsurge of studying, exploiting, and planting of seabuckthorn commenced throughout the northern, the north-western, and the south-western parts of China.

Why did seabuckthorn draw attention over other plants used in soil and water conservation? And why on a very prominent scale? This is explained by the unique characteristics of seabuckthorn that are summarised below.

1. It is a deciduous shrub and is widely distributed throughout the temperate zones of Asia and Europe and throughout the subtropical zones of Asia at high altitudes. Growing at altitudes ranging between a few metres to 5,200 metres, seabuckthorn (*Hippophae*) can resist low temperatures of up to - 43° C and can withstand heat of 40° C. Some species grow well in

regions that only have a precipitation of about 300mm while others can endure inundation. Some species grow in soils with a pH of 9.5 while others grow even in soils that contain 1.1 per cent salts.

2. Seabuckthorn has a highly developed root system and therefore presents an excellent biotic choice for holding the soil on a fragile slope. In many locations, a five-year old plant will have a tap root of up to three metres deep and horizontal roots extending between six to ten metres. Two or three years after its plantation, root turion seedlings sprout from the horizontal roots creating many new generation plants. With only four plants spaced out two to four metres apart, the entire area surrounding these plants will be completely covered within three to five years. In the planted areas, the loss of topsoil caused by seasonal monsoons will decrease to less than 30 per cent and more than 80 per cent of water will be held in the ground.

3. Seabuckthorn also has an outstanding ability to take root even in poor soils, because of its ability to fix nitrogen directly from the air through the nodules in its roots. It is estimated that about 180kg of nitrogen/hectare/annum can be fixed in the soil around seabuckthorn forests. The seabuckthorn roots also act to transform insoluble organic and mineral matters in the soil into more absorbent states. In terms of ability to improve the physical and chemical properties of soil, seabuckthorn, as a pioneer plant within a fragile and marginal context, has had remarkable success.

4. There is also an extraordinary economic aspect to seabuckthorn. A natural seabuckthorn forest can yield 750 to 1,500kg of berries per hectare. Its small, orange-coloured fruit is a storehouse of vitamins and important bioactive substances. The Vitamin C content is 5 to 100 times higher than any other fruit or vegetable known. Its pulp and seeds contain high quality oil which is regarded to be very important for its medical value. Thus, the seabuckthorn fruit is being used as a raw material for producing food, medicines, and cosmetics. In addition, the seabuckthorn plant is a good source of firewood. In a six-year old seabuckthorn forest, each hectare can produce 18 tons of firewood, equal to nearly 12.6 tons of standard coal.

5. Many years ago, people knew that seabuckthorn could serve as a water and soil conservation plant but few people knew about its huge economic benefits. In the valleys and mountains, seabuckthorn plants grow, flourish, and die naturally. Because of its ability to fertilise soil, farmers used to dig out seabuckthorn and then plant potatoes or other crops on fields from which seabuckthorn had been removed. Sometimes, for reforestation, they destroyed seabuckthorn bushes instead of planting them. That is why massive seabuckthorn forests could only be seen in very remote areas.

   After the economic benefits of seabuckthorn were revealed, farmers came to consider seabuckthorn a valuable resource. Increasing cultivation of seabuckthorn attests its multipurpose usage and tremendous value-added properties. For the farmers living in the mountains, seabuckthorn offers them the opportunity to maintain a more sustainable livelihood, while protecting their land from soil erosion. The use of seabuckthorn illustrates how low input costs and careful planning can lead to quite substantial benefits; a good example of mountain perspective-oriented, sustainable development. Seabuckthorn thus qualifies as a unique option for the simultaneous management of several problems emanating from the fragility, marginality, inaccessibility, and diversity characterising mountain areas.

In the following discussion, first (Chapter 2) we introduce seabuckthorn by describing its botanical features and its geographical spread. The next chapter (3) deals with the harnessing of seabuckthorn for economic gains. A variety of economic usages in China and the former USSR are described with quantitative evidence. In Chapter 4, environmental functions of seabuckthorn (i.e., for resource conservation/rehabilitation) are described by extensively narrating the experiences from the Loess Plateau in China. Some operational details on plantation and management of seabuckthorn are discussed in Chapter 5. The last chapter briefly indicates the scope and prospects of popularising seabuckthorn as a multipurpose option in different parts of the HKH Region. It also describes experiences with seabuckthorn cultivation and commercial exploitation in three countries, namely China, Mongolia, and Russia.

II. The Features of Seabuckthorn

Name and Taxonomical Position

Seabuckthorn is a general term given to the shrub-tree *Hippophae Linn.* This genus belongs to the family *Elaeagnaceae* which consists of several species and sub-species among which the most important is *Hippophae rhamnoides Linn*, commonly known as seabuckthorn. Because it is mainly this species that has been used for economic and ecological purposes, the term 'seabuckthorn' usually means *Hippophae rhamnoides*. This species is widely distributed in many places throughout Eurasia. It has evolved over a long period of time and has varied so much that it has to be classified into different units.

In 1971, Finnish taxonomist Arne Rousi divided this species into 9 sub-species that he found growing from Norway in Scandinavia to the Northeast of China. Of these sub-species, *Hippophae rhamnoides L.*, sub-species *sinensis Rousi*, is commonly used in China. In this paper, seabuckthorn stands for this sub-species or Chinese seabuckthorn. However, the other species and sub-species will also be mentioned because they have many characteristics and can be used in different ways. Arne Rousi recognised three species of *Hippophae*: *Hippophae rhamnoides L., Hippophae salicifolia D. Don., and Hippophae tibetana Schlecht.*

Hippophae rhamnoides L. has been further divided into nine sub-species:

H. Rhamnoides L., Subsp. *carpatica Rousi*
H. Rhamnoides L., Subsp. *caucasica Rousi*
H. Rhamnoides L., Subsp. *gyantsensis Rousi*
H. Rhamnoides L., Subsp. *mongolica Rousi*
H. Rhamnoides L., Subsp. *sinensis Rousi*
H. Rhamnoides L., Subsp. *turkestanica Rousi*
H. Rhamnoides L., Subsp. *yunnanensis Rousi*
H. Rhamnoides L., Subsp. *rhamnoides*
H. Rhamnoides L., Subsp. *fluviatilis Rousi*

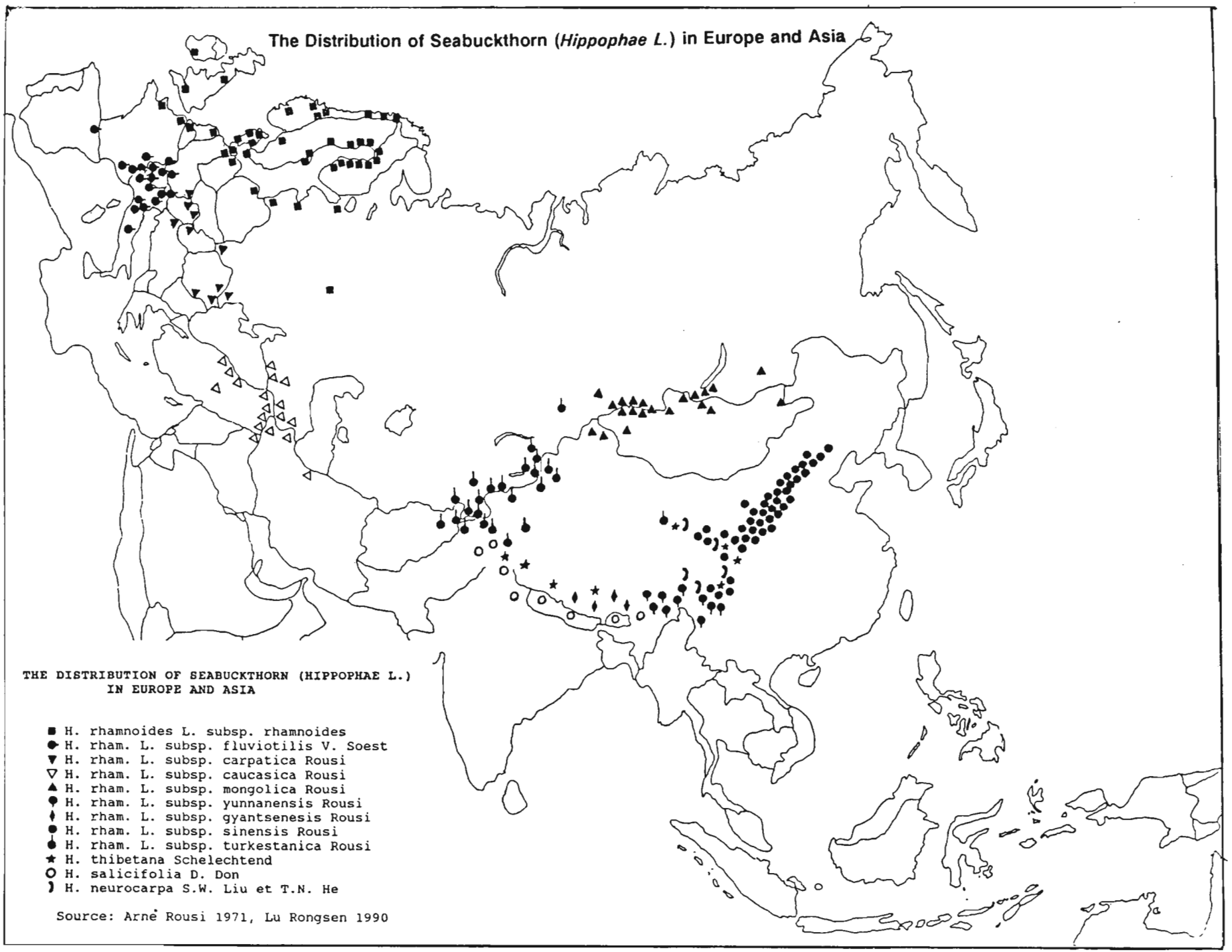
In 1978, Chinese taxonomists, Liu Shangwu and He Tinnong, reported the existence of a new species, *H. neurocarpa S.W. Liu et. T.N. He*, from the Qinghai-Xizang Plateau. Since then four species of *Hippophae L.*, viz., *H. rhamnoides* (including nine sub-species), *H. salicifolia, H. tibetana*, and *H. neurocarpa*, have been recognised by Chinese scientists. In 1988, another Chinese taxonomist, Lian Yongshan, introduced a new classification system for the genus. He upgraded *H. rhamnoides*, subsp. *gyantsensis*, to an independent species, viz., *H. gyantsensis (Rousi) Lian* of the *Hippophae* and introduced two groups, the coat and coatless groups. So, according to Lian's classification system there are 5 species and 8 sub-species. Lian's classification is, however, yet to gain wide recognition.

The distribution of these seabuckthorn species throughout Europe and Asia is shown in Map 1. A general glance at the global distribution pattern of *Hippophae spp.* indicates that it is concentrated in the Hindu Kush-Himalayan Region, adjoining areas of China, and parts of Europe and the former USSR as well as the Scandinavian Region. All of these areas are climatically cold-temperate.

Plant Morphology

Seabuckthorn is a deciduous, usually spinescent, shrub. In exceptional locations, e.g., in the northern or north-western mountain areas of China, it is a small tree growing up to a height of 1 to 5m. However, it can grow up to more than 15 to 18m in forest areas with abundance of water, e.g., on river banks. With brown or black rough bark and a thick grayish green crown, it often forms a massive grove on the river banks or dry river beds. Its natural lifespan appears to be at least 60 to 70 years.

In recent years, many large seabuckthorn trees have been found. In Muli County, Sichuan, there is a tree with a height of 16m, a trunk girth of 5.3m, and a crown diameter of 16.1m. It is estimated that its age is more than 320 years and it is still bearing fruit. Another tree found in Zhongdian County of Yunnan Province recorded a height of 17.5m, a trunk girth of 3.8m, and a crown diameter of 15.5m. It is estimated that its age is more than 300 years.


The Distribution of Seabuckthorn (*Hippophae L.*) in Europe and Asia
THE DISTRIBUTION OF SEABUCKTHORN (HIPPOPHAE L.)
IN EUROPE AND ASIA
H. rhamnoides L. subsp. rhamnoides
H. rham. L. subsp. fluviotilis V. Soest
H. rham. L. subsp. carpatica Rousi
H. rham. L. subsp. caucasica Rousi
H. rham. L. subsp. mongolica Rousi
H. rham. L. subsp. yunnanensis Rousi
H. rham. L. subsp. gyantsenesis Rousi
H. rham. L. subsp. sinensis Rousi
H. rham. L. subsp. turkestanica Rousi
H. thibetana Schelechtend
H. salicifolia D. Don
H. neurocarpa S.W. Liu et T.N. He
Source: Arne Rousi 1971, Lu Rongsen 1990

The leaves are small (usually 3 to 8 cm long and 0.4 to 1.0 cm wide), linear, lanceolate, and covered on the back side with silvery stellate scales that reflect sunshine and reduce moisture loss.

Separate Male and Female Plants

Seabuckthorn bushes are either male or female. The males produce pollen and have flowers without petals. Each flower contains four stamens. When the atmospheric temperature ranges from 6°C-10°C, the anthers split and the pollen is blown out by the wind in large quantities. The females produce fruit and seeds and have flowers, also without petals. Each flower contains one ovary and one ovule. The female flower depends almost entirely on the wind for pollination.

Neither the male nor the female flowers have nectaries, so they cannot attract bees or other insects to collect nectar. Honeybees and a variety of other insects often visit the male flower only to forage pollen for protein, but they rarely visit the female flowers.

Seabuckthorn floral buds are mostly mixed with vegetative buds and are rarely pure. Floral buds appear on the current season's growth, mainly in the summer or the autumn. They usually open in the following spring.

Generally, the male floral bud consists of four to six flowers, the female floral bud consists of one flower and rarely two or three. The sex of a young seabuckthorn plant cannot be judged until the first flower buds appear. In precocious plants this may be in the third year, whereas in slow plants it may happen in the fifth or the sixth year. This makes it difficult to identify and give the right position to the male plant in a plantation, or to root out the unwanted male and inferior females when they are at the nursery stage.

Fruit

Seabuckthorn bears a special fruit, that is different from other common fruits or berries. Morphologically it develops from an ovary and a calyx tube which is closely connected to the ovary. Actually the fruit is a combination of an unsplit, fleshy, expanded calyx tube and an ovary. In other words, the expanded, juicy calyx tube is the important part with economic value.

The seed is surrounded by a parchment-like ovarian wall. Usually, the seed is ovate-oblong with a length of 4 to 7 mm, a breadth of 2.5 to 3.5mm, and a thickness of 1.6 to 2.2 mm. The skin of the seed is greyish-brown or dark brown, leathery, and lustrous.

The time taken from flowering to fruit maturation is 12 to 15 weeks. Young fruits are hard and greenish, but turn soft and orange or orange-red as they mature.

Seabuckthorn bushes or trees hold the mature fruit for several months, this gives ample time to harvest them. In a natural seabuckthorn forest, fruits can remain on the branches until the following spring. During this period (usually cold winter), the fruits gradually shrink but do not fall. Therefore they become the favourite food of animals, especially birds.

Roots

Seabuckthorn has a very strong root system that taps the underground moisture. Bushes that are a mere 5 years old have been found with taproots of up to 1.10m deep and horizontal roots of up to 2.58m wide in the Loess Plateau. Some mature shrubs have been found with roots extending as far as 10m in a horizontal direction. Some 80 per cent of its feeding roots are in the topsoil (0.2 to 0.8m). Often young plants have taproots twice the height of the plant and root widths three times wider than the crown of the plant above the ground. With its strong root system, seabuckthorn can suck up more water and fertiliser than other plants.

The seabuckthorn root system is so extensive that its roots can branch many times in a growing season and form a complex network of roots. A lot of root turion seedlings grow upwards from the horizontal roots and form new bushes. When plants are buried with sand and mud sediments, massive adventitious roots grow from root collars. Some of the adventitious roots extend to form a new horizontal root system. From this, new turion seedlings grow again. In other words, one plant will propagate massive bushes or a small forest in several years. This is the reason why seabuckthorn bushes play an important role in protecting river banks, preventing floods, and clogging mud which would otherwise be washed away in flood waters. In fact these bushes are more effective than any construction work.

A symbiotic mycorrhizal fungus, which is identified as *Flankia*, has been found on seabuckthorn roots. This

symbiosis between the fungus and seabuckthorn results in root nodule formation that can fix the maximum amount of atmospheric nitrogen. It is estimated that the capacity of seabuckthorn roots to fix nitrogen is twice that of soyabean.

A land covered with six year old seabuckthorn bushes contains organic matter of up to 2.2 per cent and nitrogen of up to 0.12 per cent; i.e., 12.2 times and 1.9 times higher respectively than land located on river banks in the same area.

Besides fixing nitrogen, the perennial root nodule has the function of transforming difficult to dissolve organic and mineral matter into an absorbable state.

Environmental Requirements

Temperature

Seabuckthorn belongs to the group of thermophilic plants. This can be proved by examining its germination temperature. Usually, the seeds of apple and cherry germinate at 1 to 3°C, having passed through their physiologically dormant period. But seabuckthorn needs a higher temperature than these plants. For example, at 10-12°C, only 13.2 per cent of seabuckthorn seeds germinate over a period of 47 days. But if the temperature goes up to 24-26°C, 95 per cent of the seeds will germinate within six days.

Notwithstanding, an adult seabuckthorn plant can withstand extremely low temperatures; during the winter season air temperatures of -10 to -13°C are common in its natural habitat. It has been reported that seabuckthorn can endure an extreme minimum temperature of -40.4°C (in Northern China) and -43°C (in the Gorky State of the former USSR) without sustaining long-term damage.

It would appear, therefore, that low temperatures during winter are not an important limitation to seabuckthorn cultivation. On the other hand, the high temperature during summer (maximum air temperature >30°C, maximum ground surface temperature >55°C) often causes burning on seedlings, sometimes killing them. This is the reason why efforts to introduce seabuckthorn from mountain areas to the plains have often failed.

It has been mentioned that *Hippophae* contains several species and sub-species that are widely distributed throughout various physical environments of Eurasia, therefore it is understood that they survive in different climatic conditions. The Chinese seabuckthorn (*H. rhamnoides L.*, subsp. *sinensis*) spreads throughout vast mountain areas with annual mean temperatures of 3.6 to 10.7°C. The Central Asian seabuckthorn (*H. rhamnoides L.*, subsp. *turkestanica*) is distributed throughout the arid desert area where the annual mean temperature is from 2.7-7.5°C. The Tibetan seabuckthorn (*H. tibetana*) is scattered throughout the cold plateau where the annual mean temperature is from -4.7 to 1.1°C.

Moisture

Generally, seabuckthorn is a hydrophilous plant. Its natural habitat, where it thrives well, includes river banks, valleys, and shady slopes of mountains where air temperatures and soil conditions do not suit many agricultural crops. Most natural populations grow in areas receiving 400 to 600mm of annual precipitation. Seabuckthorn should not be planted on sites where the rainfall is less than 400mm, the underground water below 2m, and where there are no irrigation facilities.

In some places, although precipitation is from 400 to 500mm, soil moisture could be critical during the spring season, the period during which flowering and young fruit development occur. Owing to the spring drought, the young fruits could wither or fall.

For economic reasons, 600 to 700mm of annual moisture appears to be most suitable for establishing plantations, and, in most areas, it is probably needed to ensure commercial success. However, where drainage is good, extra water may not be detrimental; seabuckthorn has been observed to grow satisfactorily along river banks where flooding often takes place, especially in summer.

Natural seabuckthorn populations are widely distributed throughout the temperate zones of Asia and Europe and in the subtropical zone of Asia at higher altitudes. In the mountain areas, the most suitable altitudes are between 1,500 to 2,500m, where precipitation is about 600mm and the annual mean temperature about 4° to 8°C, as a result of which plants grow well and produce large, good quality fruit.

Altitudes between 1,000 to 1,500m, where precipitation is about 500mm and the annual mean temperature is 8 to 10°C,

are also suitable and plants grow and bear normally. But altitudes below 1,000m and above 2,500m are not so suitable, and, although plants do grow, they produce small and poor quality fruit.

Although seabuckthorn is a hydrophyte, as described above, it has developed some xerophytic features over its long evolutionary course. For example, its leaves are small and narrow, covered with thick cuticles and dense stellate hairs on the back, and there are lots of thorns on the stems. All these features help seabuckthorn to reduce water drainage; thus seabuckthorn can withstand atmospheric drought. Massive seabuckthorn bushes with good flowers and fruit exist in the arid river valleys of Central Asia, Kazakhstan, Azerbaijan, and Xinjiang, China, where precipitation is less than 400mm, the weather windy and dry, and where there are many hours of sunshine. This demonstrates the above-mentioned characteristics of seabuckthorn.

Wherever the plant is grown, good drainage is vital; seabuckthorn cannot survive water logging. Marshy wasteland should never be planted with seabuckthorn, because the root system would be destroyed because of the lack of oxygen.

Soil

In the natural environment, thriving seabuckthorn plants are found on sloping, well-drained soil with silt and on the banks of rivers, lakes, and seashores. This is the reason why many researchers considered these soils to be most suitable to the biological characteristics of seabuckthorn. Indeed, these soils provide seabuckthorn with enough water, air, and fertiliser, thus making it grow well and producing fine fruit. Some plants have proved successful even on sandy soils and stony soils. Heavy clays may be suitable in some areas but only if internal drainage is good. The plant cannot withstand soils with poor porosity. Excess water and lack of air would kill the plant.

Extensive measurements taken for wild seabuckthorn populations in north and northwestern China have shown that the plants thrive in soils ranging from pH 6 to 7, but in other places, they have been found in soils ranging from pH 5.5 to 8.3. This indicates that soil acidity and alkalinity are probably not limiting factors. For a long time, there has been a wrong notion that seabuckthorn as a plant does not need more soil nutrients. This is not true. The experiences on plantations have shown that the productivity of seabuckthorn can be increased greatly by providing enough water and fertiliser. For example, in Lisavenko Institute of Horticulture, Siberia, the yield of cultivated seabuckthorn increased up to 13,000 kg/ha (the yield of natural bushes is only 300-700 kg/ha).

In fact, seabuckthorn needs more nutrients during the period of growth and fruit development. Seabuckthorn can obtain nitrogen through root nodules from the atmosphere. On the Loess Plateau, China, where seabuckthorn populations dominate, the soil has been reported to be phosphorus deficient, but further studies revealed that seabuckthorn rhizosphere soil contains 2 to 5 times more rapidly available phosphorus than soil without roots. This means that the secretion of the root can transform the insoluble phospho-calcium compound ($[Ca_2\ (PO_4)_2]_3\ CaCo_3$) into soluble phosphorus, which is then absorbed by the roots.

Salinity

Seabuckthorn is also a salt-tolerant plant as has been demonstrated in many places, e.g., Siberia, Central Asia, Azerbaijan, and Xinjiang, China, where seabuckthorn populations grow well on the soils of wastelands, deserts, and dunes of the seashore that have highly concentrated salt contents.

When tested in the laboratory, some varieties of seabuckthorn showed increasing growth of seedlings when about 0.15 per cent of sodium chloride (NaCl) solution was added. Furthermore, before sowing, soaking seabuckthorn seeds in 0.15 per cent of NaCl solution for 24 hours not only produced healthy seedlings but also increased the output of standard seedlings in nurseries.

An experiment carried out in Shaanxi, China, showed that seabuckthorn bushes can be used to reduce salinity: a plot was planted with willow and it contained 0.32 per cent of salt, but, when the plot was planted with willow and seabuckthorn, the salinity decreased to 0.1 per cent. Long-time tolerance of salinity on plantations has not been demonstrated, especially in irrigated conditions. The build-up of salinity in the root zone could be a future problem for plantations with restricted drainage and which contain salt water.

III. A Multipurpose Plant Species for Mountain Farming Systems

Seabuckthorn is described as the most appropriate multipurpose option for mountain areas because: (i) it helps in reconciling high productivity through intensive land use in the mountains with land-extensive usages dictated by the fragility and marginality of mountain slopes. It has the potential to support high value-added products which can be integrated within the market economy, as well as to support the rehabilitation and upgrading of marginal or fragile slopes through soil-binding and building in mountain areas.

Depending on the circumstances and development priorities, either or both categories (i.e., resource conservation versus economic productivity) may be emphasised. In the present chapter, we deal with the possibilities of harnessing seabuckthorn for mountain farming systems. The latter, as is well-known, covers a combination of different land-based activities, including cropping, forestry, and animal husbandry. Accordingly, first we discuss the natural potential of seabuckthorn to support various product (and processing) - based, income-generating activities. Experiences in harnessing this potential in countries such as China and the former USSR are discussed. The section concludes with other countries where seabuckthorn is used largely as a source of biomass for fuel, fodder, etc.

Purpose

Seabuckthorn has been used by human beings for at least 12 centuries now, as recorded in the Tibetan medicinal classics - "the *rGyud bzi*" (i.e., the Four Books of Pharmacopoeia), completed in the Tang Dynasty (618-907 A.D.). However, it is only in recent decades that people have had a better understanding of seabuckthorn. The scholars who are engaged in scientific research on seabuckthorn in various countries have revealed the important values of seabuckthorn to human beings by carrying out a large number of scientific experiments. With the gradually worsening quality of the environment and the overriding poverty in many countries today, seabuckthorn has attracted a great deal of attention from scientists and engineers all over the world because of its concentrated ecological, social, and economic benefits.

Some countries have already adopted measures to protect natural seabuckthorn resources, carried out large-scale, artificial seabuckthorn afforestation, and have also produced seabuckthorn drinks and chemical products. In depth scientific research on medicines and further exploitation and usage of seabuckthorn is developing quickly. Today, as the following discussion shows, seabuckthorn is used in many countries in many ways, e.g., in food industries, medical industries, in cosmetic preparations, and as forage, fuel, and ornamental plants.

Natural Potential: The Basic Composition of the Fruit

A typical seabuckthorn plant usually consists of a bush bearing clusters of juicy fruit. The fruit is generally about the size of a small pea and is greenish in colour in the beginning but turns orange or red as it matures. Chemical analytical data show that seabuckthorn fruit is rich in nutrients such as carbohydrates, organic acids, amino acids, and vitamins. The vitamin content of seabuckthorn is much higher than any other fruit or vegetable (see Table 1).

The Vitamin C content of seabuckthorn is 3 to 16 times higher than that of the Kiwi fruit (*Actinidia sinensis*) which is very famous for its high Vitamin C content. This is the reason why the fruit of seabuckthorn is usually used to make soft drinks and other similar food products. Because of its various rich nutrients, the seabuckthorn beverage is considered to benefit people such as sportsmen, manual workers, children, the aged, and pregnant women by building up their strength.

Another feature of the seabuckthorn fruit is that both the pulp and the seed contain high quality oil which is considered to be a carrier of many concentrated bioactive substances. By determination, the oil content accounts for 1.5 to 3.5 per cent in the pulp and 9.9 to 19.5 per cent in the seeds respectively. Comparative qualities of seabuckthorn oil and other nutrient oils are shown in Table 2. From Table 2, it can be seen that unsaturated acid makes up more than 80 per cent of the total fatty acids. In unsaturated

acids, more than 60 per cent are linoleic and linolenic acids and these are considered to be indicators of the good quality of seabuckthorn oil. In addition, β-carotene and Vitamin E contents in seabuckthorn oil are much higher than those of other nutrient oils. For this reason, the oil of seabuckthorn is thought to be a valuable nutrient oil or medicinal material.

Table 1: Comparison of the Vitamin Contents of Seabuckthorn and Other Fruits and Vegetables (mg/100g)

	V_A	V_{B1}	V_{B2}	V_P	V_C	V_K
Seabuckthorn	11.00	0.04	0.56	1000.0	300-1600	100-200
Cili (*Rosa roxburghii*)	4.83	0.05	0.03	2900.0	1000-3000	-
Kiwi fruit (*Actinidia sinensis*)	-	-	-	-	100-470	-
Hawthorn	0.82	0.02	0.05	-	100-150	-
Orange	0.55	0.08	0.03	-	50.0	-
Tomato	0.31	0.03	0.02	-	11.8	-
Carrot	4.00	0.02	0.05	-	8.0	-

Source: Xu Zhonglu 1956, Tian Houmou 1985, Wang Guoli 1987, and Luo Dengyi 1984, Lu Rongsen 1990

Table 2: Comparison of the Composition of Fatty Acid, Vitamin E, and β-Carotene in Seabuckthorn Oil and Other Selected Nutrient Oils

	Fatty Acid Component (%)				
	Saturated Acid	Unsaturated Acid	Linoleic and Linolenic Acid	Vitamin E (mg/100g)	β-Carotene (mg/100g)
Seabuckthorn oil	13.7	86.0	64.6	202.9	248.90
Wheat embryo oil	-	-	-	144.5	-
Safflower oil	8.0	92.0	81.4	3.3	-
Maize oil	15.2	84.8	48.3	34.0	0.81
Soyabean oil	14.8	83.7	62.8	7.5	0.11

Source: Wang Guoli 1986, Lu Rongsen 1988, Zhang Fushun 1987, and Zhong Chongju 1989

In the beginning of the 1980s, seabuckthorn's broad economic and ecological possibilities gained the attention of the Chinese. Farmers and rural entrepreneurs in the northern mountain areas of China began collecting and processing the fruit from natural seabuckthorn bushes and producing various beverages. The evaluation of the results stimulated many researchers to study seabuckthorn and to produce significant achievements.

From 1983 to 1986, Ma Zhiben systematically analysed the chemical composition of the Chinese seabuckthorn fruit (*H. rhamnoides L.*, subsp. *sinensis*) collected from Shanxi, China, and obtained many interesting data. From Table 3, it can be seen that the main composition of seabuckthorn juice (or pulp) is soluble sugar, organic acids, and vitamins. The soluble sugar content accounts for 7.1 per cent, which is less than that found in the common apple (8-15%) or

orange (8-13%), thus it is rather insignificant. But the organic acid content accounts for 4.4 per cent which is more than that found in most fruits (for example, lemon is well known for its high acid content and it only contains 1-2%). The most prominent feature of its juice is that it is rich in Vitamin C (780.0mg/100g). This content is higher than that of any fruit or vegetable (see Table 1). Vitamin E and carotene account for 1.1mg/100g and 7.7mg/100g respectively, and these are also higher than those of most fruits and vegetables. Because of its abundant organic acid and Vitamin C content, seabuckthorn juice is considered to be suitable for making various beverages. In addition, there is some tannic acid in the juice (0.5%) and this causes the beverage to have a special, pleasant taste.

Table 3: Chemical Composition of Different Parts of the *H. rhamnoides*, Subsp. *Sinensis* Fruit

Fruit Part	Dry Matter Content (%)	Soluble Sugar (%)			Vitamin (mg/100 g)			Organic Acid (%)	Oil Content (%)	Protein Content (%)	Tannic Acid Content (%)
		Reducing	Non-reducing	Total sugar	V_C	V_E	Carotene				
Pulp	22.9	6.95	0.22	7.17	780.9	1.10	7.7	4.40	2.05	0.4	0.50
Seed	82.8	1.60	4.24	5.84	149.0	6.35	3.3	0.95	8.36	19.6	3.96
Fruit	26.0	6.05	0.24	6.29	741.0	1.79	7.3	4.35	2.20	1.2	0.57

Source: Ma Zhiben 1987

The other component of seabuckthorn juice is free amino acid (Chen Tigong 1988, see Table 4). From Table 4, it can be seen that there are 18 kinds of free amino acid in seabuckthorn juice, among these 8 are necessary for the human body. They are threonine (6.24 mg/100g), valine (2.85), methionine (1.12 mg/100g), leusine (1.94 mg/100g), lysine (3.49 mg/100g), trytophane (0.51 mg/100g), isolencine (0.97 mg/100g), and phenylalacine (3.21 mg/100g).

Micro-elements are considered to play an important role in living things and the human body. They display a high catalytic activity in some biochemical reactions and they are parts of enzymes which activate or passivate the reactions.

In 1988, Chen Tigong determined 27 elements in the Chinese seabuckthorn fruit. These elements and their contents are given in Table 5.

Table 4: Contents of Various Free Amino Acids in *H. rhamnoides L.*, Subsp. *Sinensis* Juice

Free Amino Acids	mg/100g	Free Amino Acids	mg/100g
Aspartic acid	3.72	Isoleucine	0.97
Threonine	6.24	Leusine	1.94
Serine	5.31	Tyrosine	1.79
Glutamic acid	2.65	Phenylalacine	3.21
Clycinin	0.64	Histidine	1.06
Alanine	2.50	Lysine	3.49
Cysterine	0.82	Arginine	0.47
Valine	2.85	Proline	12.28
Methionine	1.12		
Trytophane	0.51	Total	51.57

Source: Chen Tigong 1988

Table 5: Contents of the Elements in *H. rhamnoides L.*, Subsp. *Sinensis* Dried Fruit

Elements and their Contents (mg/kg)					
Ba	11.66	Be	0.095	Cr	2.535
Cu	-	La	6.655	Mn	93.68
Nb	-	Ni	4.985	P	959.62
Sr	5.15	Ti	44.91	V	2.725
Y	0.97	Zn	30.44	Zr	0.875
Al	2593.93	Fe	3264.28	Mg	2222.2
Ca	3119.33	Si	83.775	As	24.803
Mo	7.285	Sn	8.663	B	-
Pb	1.215	Cd	-	Se	5.015

Source: Chen Tigong 1988

Among the 27 elements, the Al, Ca, Fe, Mg, P, Mn, Ti, Zn, Si, As, and Ba contents are good, but the Be, Zr, Y, and Pb contents are poor. No traces of Cu, Nb, Cd, or B were found.

Usually, the pulp oil and the seed oil are extracted one after the other. At room temperature, the pulp oil is a light gold-coloured fluid but the seed oil is an orange or orange-red liquid. Their properties are shown in Table 6.

Table 6: Properties of *H. rhamnoides L.*, Subsp. *Sinensis* Oil

	Pulp Oil	Seed Oil
Specific gravity D_4^{20}	0.92	0.93
Refractive index N_{20}^{D}	1.4698	1.4763
Specific optical activity	+ 30°	+ 35°
Acid value (mg KOH/g)	4.3	6.4
Saponification value (mg KOH/g)	195	180
Iodine value	65	124
Sulfocyanic value	47.3	88.1
Unsaponificable matter %	1.47	0.92

Source: Chen Tigong 1988

From Table 6, it can be observed that the physical and chemical properties of seabuckthorn are different from each other. The specific gravity of the pulp oil (0.92) is a little lower than that of the seed oil (0.93). The refractive index of the pulp oil (1.4698) is also a little lower than that of the seed oil (1.4763). The iodine value of the pulp oil and the seed oil are 65 and 124 respectively, which means that the unsaturated compounds of the pulp oil are less than those of the seed oil, and this can be proved by the fatty acid analysis (see Table 2). Unsaponificable matter mainly implies fat-soluble vitamins (V_E, V_K, and so on), pigments (such as carotene and lycopene), steroids, alcohols, and hydrocarbons. The unsaponificable matter of the pulp oil is 1.47 per cent and this is more than that of the seed oil (0.92%). This means that the pulp oil contains more bioactive substances than the seed oil does.

Differences between pulp oil and seed oil also exist in the oil content, the fatty acid compositions, and the bioactive substances.

Ma Zhiben analysed the fruit oil of seabuckthorn from Shanxi, China, and his results are shown in Tables 7 and 8.

Table 7: Principal Chemical Components of *H. rhamnoides L.*, Subsp. *Sinensis* Oil

Part of Fruit Analysed	Oil Content (%)	Iodine Value	Acid Value	Carotene (mg/100g)	Vitamin E (mg/100g)
Pulp	6.8 - 7.5	47.7	6.3	54.0 - 102.6	40.1 - 62.8
Seed	10.2 - 12.4	14.0	6.2	27.8	65.7 - 104.1
Fruit	7.4 - 8.0	86.0	6.3	56.0 - 97.2	45.9 - 93.2

Source: Ma Zhiben 1987

Table 8: Fatty Acid Components of *H. rhamnoides*, Subsp. *Sinensis* Oil (%)

Part of Fruit analysed	Lauric Acid	Myristic Acid	Palmitic Acid	Hexa-decenoic Acid	Stearic Acid	Oleic Acid	Linoleic Acid	Linolenic Acid	Other Acid	Saturated Acid	Unsaturated Acid
Pulp	0.1	1.0	31.2	35.0	0.5	25.2	4.5	2.1	0.4	32.8	66.8
Seed	0.1	0.2	8.7	0.6	2.0	23.7	37.0	27.6	0.1	11.0	88.9
Fruit	0.1	0.8	26.9	30.5	0.7	24.4	9.2	7.1	0.3	28.5	71.2

Source: Ma Zhiben 1987

From Table 7, it can be seen that the oil content of the pulp and the seed are respectively 6.8 - 7.5 per cent and 10.2 - 12 per cent; these are normal and representative of the northern mountain areas of China.

Although the oil content of seabuckthorn is not as much as the amount found in most oil crops, its nutritive and medicinal values are much more than those of most oil crops because it contains a lot of fat-soluble bioactive substances. From Table 7, it can be seen that the carotene content of the pulp oil is 54.0 - 102.6mg/100g, which is more than that found in any fruit or vegetable (see Table 1), and the Vitamin E content of the seed oil is 65.7 - 104.1mg/100g, which is more than that found in any oil crop (see Table 2).

Besides carotene and Vitamin E, Vitamin K and phospholipin, in both the pulp and the seed oil, were determined by Zhang Fushun et al. (1987).

The Vitamin K content is about 109.8 to 230.0mg/100g (seed oil) and 58.9 to 64.4mg/100g (pulp oil), which are more than those contained by most horticultural crops. Vitamin K is called the coagulation vitamin because it plays a catalytic role in forming prothrombin; it can promote normal coagulation of the blood. The phospholipid content is about 0.69 - 1.77 per cent (seed oil) and 0.24 - 0.27 per cent (pulp oil). It is said that the membrane contains phospholipid which plays an important role in regulating the membrane's osmotic function.

The fatty acid composition of seabuckthorn is shown in Table 8 and it also shows that the fatty acid contents of the pulp oil and the seed oil vary.

The pulp oil contains unsaturated acids of 68.8 per cent and among the 9 fatty acids, nexadecenoic acid (35.0%), oleic acid (25.2%), and linoleic acid (45%) are dominant, and the seed oil contains unsaturated acids of 88.9 per cent, among which oleic acid (23%), linoleic acid (37.0%), and linolenic acid (27.6%) are dominant. According to medical theory, unsaturated acids are beneficial to the health of the human body, especially linoleic acid and linolenic acid which are

often used for curing diseases relating to the cardiovascular system and to high blood fat content. In this case, the seed oil is better than the pulp oil because the former contains 64.4 per cent of linoleic acid and linolenic acid, whereas the latter contains only 6.6 per cent.

Besides the above-mentioned basic components of the juice and oil many other components have been found over the past 20 years. Although the contents of these components are not great in quantity, they have important nutritional and medicinal functions.

Carotenoids

β-carotene is dominant in carotenoid. Its content varies depending upon place of origin and the part analysed, for example, the seed oil from Longxi, Shaanxi, contains β-carotene 159.8mg/100g but that from Hetain, Xinjiang, contains 1159.6mg/100g. The highest carotene content is 9059.6mg/100g, found in the pulp oil from Hetain, Xinjiang (Zhang Fushun 1987).

The other carotenoids are α-carotene, γ-carotene, zeaxanthin, polyzlycopene-3, and lycopene. It has been proved that lycopene can also prevent Vitamin A deficiency in human beings and animals and also stimulate their growth.

Flavonoids

Seabuckthorn fruit is rich in flavonoids. In 1979, Xiao Zhuyin et al. studied the flavonoid constituents of the Chinese seabuckthorn fruit from Western Sichuan, China. They found that the juice and dried fruit residue contained flavonoid of 0.2 per cent and 0.55 per cent respectively. By means of thin layer chromatographic analysis, 7 different flavonoids were found. In addition, two main monomers were separated from others and identified as isorhamnetin and quercetin. Later, the flavonoids extracted from seabuckthorn fruit were proved to be effective for curing high blood fat content, coronary heart diseases, and angina pectoris, especially in reducing serositic ceride.

Harnessing of Potential

Despite the scientifically proven potential of seabuckthorn for manufacturing several high value products for human consumption, its harnessing is constrained by the lack of appropriate technologies and facilities to process the same. There are a few countries, such as China and the former USSR, which very effectively harness seabuckthorn in industries relating to food, medicinal, and other items.

Use in Food Industries

Although the Russians began to use seabuckthorn fruit for making wine, jam, and jelly in the 19th century, this was not on an industrial basis but merely for domestic use. When seabuckthorn as a fruit tree was introduced into orchards and cultivated on a larger scale, especially after the Second World War, many nutritionists and pharmacologists proved that the seabuckthorn fruit contained many kinds of nutrient and bioactive substances and could be used in food and medicines. This encouraged the establishment of modern seabuckthorn food industries.

Since the 1940s, many factories have been built that produce seabuckthorn food, seabuckthorn beverages, and other products. Products, such as juice, jam, jelly, and syrup have become very popular in the former USSR. It is estimated that, currently, in areas of the former USSR, the seabuckthorn orchards produce 50 thousand tons of fresh fruit, worth 115 million Rbl. (2,300 Rbl. per ton) annually.

Along with the traditional products, various new ones, such as seabuckthorn condensed juice, mixed juice, seabuckthorn carrot jam, candied fruit, seabuckthorn "cheese", assorted seabuckthorn candies, seabuckthorn butter, seabuckthorn tea, and seabuckthorn health protection drinks, have been produced and marketed. In addition, according to the literature of the former Soviet Union, seabuckthorn fruit and oil have been included in the diet of astronauts (Besschetnov, V.P. et al. 1989).

Although seabuckthorn cultivation is very common in the former USSR, the demands for seabuckthorn products still have not been met. For example, in the free market of Moscow, fresh seabuckthorn fruit costs 5 Rbl. per kg which is as much as three times the price of apples. In the State-owned shops, the seabuckthorn fruit and its products are often out of stock. It is believed that the profits derived from seabuckthorn are often more than those from other fruits. For example, in processing factories the cost of production for one bottle of jam is 0.8 Rbl. and the selling price is 1.80 Rbl. This means the factory gains a profit of 1.0 Rbl. per bottle.

In the former USSR, the residues of seabuckthorn (after extracting juice and oil) have been used as food additives and are often added to bread, candies, cakes, and seabuckthorn butter. The residues have also been used as feed additives to raise animals for the fur trade. It has been proven that the seabuckthorn feed additives improve the quality of fur.

Because the demand for seabuckthorn in food and medicinal industries is so high, more than 6,200 ha of cultivated seabuckthorn plantation, which account for 15.1 per cent of the total seabuckthorn area of 41,000 ha, have been established up to now. But this too has not been able to satisfy the demand. In order to increase the productivity of seabuckthorn, the former Government of the USSR allowed horticulturists to establish private plantations not exceeding 0.1 ha. Running such an orchard, the owner makes an income of more than 1,000 Rbl. per year.

In the European part of the former USSR, amateur cultivation of seabuckthorn prevails. In the villas in the suburbs of Moscow, there are only a few residents who do not grow seabuckthorn and the saplings sell well. Almost all seabuckthorn farms are engaged in the production of saplings. Because sapling production is a profitable business, many horticulturists have built greenhouses to propagate saplings.

In Barnaul, Altay Border Region, an amateur grower built a greenhouse with 20 square metres of seedbed in which more than 13,000 seabuckthorn saplings were grown. Two years later, about 10,000 standard saplings were produced which cost 5,000 Rbl. This means a cash income of 2,500 Rbl. per year and this equals the average income per year of a worker in the former USSR.

In China, for a long time, seabuckthorn plants were used as soil and water conservation and firewood plants in most regions. However, the Tibetans and the Inner Mongolians used them as medicinal plants as well. After the establishment of New China, the afforestation scale of seabuckthorn expanded and now its plantation area has reached about 300,000 ha (see Table 21, p.45).

However, there were no food industries based on seabuckthorn fruit before the 1980s. At the beginning of the 1980s, some information about the research and use of seabuckthorn in the former USSR reached China. People realised that there were a lot of seabuckthorn resources in China that could be used. In China, the first batch of factories for making juice from seabuckthorn fruit was established in Fangshan and Youyu counties, Shanxi Province, during 1983 to 1984. Since that time, repeated tests and improvements have been carried out on the methods of picking seabuckthorn fruit, extracting raw juice, preservation, concentration technologies, and drinking formulas. After several years of tests, seabuckthorn drinks have now come on to the markets. Seabuckthorn processing factories have increased to more than 150 and are distributed in 19 provinces and autonomous regions of the country. Twenty-nine products that can be classified under 8 types have been developed with seabuckthorn as the main raw material (see Table 9).

By the end of 1990, the productive capacity of raw seabuckthorn products amounted to over 5,000 tons per year, the total output of various seabuckthorn products reached more than 150,000 tons per year, and the total output value was more than 100 million *yuan* (about 21,184,322 US$) (see Table 10).

The processing technologies and the quality of products have been continuously improved upon and seabuckthorn products have begun to capture some markets, especially in Northern China (Xian of Shaanxi, Taiyuan, Datong of Shanxi, Lanzhou, Tianshu of Gansu, and Beijing) These products are welcomed by the common people. Details of some cases are provided below.

- Seabuckthorn Food Experimental Factory, Shaanxi, produced a total output of products valued at 724,000 *yuan*, from which the taxes and profits amounted to 54,000 *yuan* in 1988. This factory produced seabuckthorn aerated water and milk with seabuckthorn juice, and they are in great demand in Xian City.

- Xian Brewery produced seabuckthorn beer in 1988. This kind of beer has a good taste and fruity fragrance and is very popular among the residents of Xian City. The most significant indication is a 38 per cent saving in grain by using seabuckthorn juice.

- Xiaojin Seabuckthorn Beverage Factory, which is located in Aba Tibetan Autonomous Prefecture, Sichuan, produced drink granules "Shajijin" which are much liked by the local people, especially the Tibetans in the mountain areas.

Table 9: Seabuckthorn Products Developed in China

Types	Varieties of Seabuckthorn Products
Raw materials	Clean raw juice, thick juice, condensed juice, pulp oil, seed oil, residue oil, raw powder, pigment, and flavone
Soft drinks	Syrup juice, fruit juice drinks (including thick juice and clean juice), carbonated juice drinks, soda water
Hard drinks	Sweet wine, medium dry wine, carbonated (bubbling) wine, champagne, and beer
Drink granules	Seabuckthorn crystals
Functional drinks	Sports' drinks, seabuckthorn syrup
Jam, sweets	Seabuckthorn jam, seabuckthorn chocolate sweets
Cosmetics	Shampoo, hair conditioner, hair dye, cosmetic beauty cream
Medicines	Medicines for treatment of cough, flavonoid liquid, compound oil suppositories, seabuckthorn extracts, etc.

Source: Pan Ruiling 1989

Table 10: Statistical Figures of Some Seabuckthorn Processing Factories in China, 1988

Name of the Processing Factories	Main Products	Output (ton)	Output Value ('000 *Yuan*)	Profit/tax ('000 *Yuan*)
Xinghuachun Fin Distillery, Shanxi	Seabuckthorn wine	450	1410	180
Zhuolu General Distillery, Hebei	Seabuckthorn wine	810	1460	600
Lifu Seabuckthorn Production Company, Beijing	Beverage	800	2100	340
Taiyuan Food and Drink Factory, Shanxi	Beverage	835	2920	280
Jianping Health Food Factory, Liaoning	Solid Drink	42	2400	200
Jianping Seabuckthorn Factory, Liaoning	Raw juice	130	270	27
Chengdu Fruit Processing Factory, Sichuan	Raw juice Beverage	150	750	60
Datong Beverage Factory, Shanxi	Beverage Champagne	1085	660	160
Nileke Seabuckthorn Factory, Xinjiang	Raw juice Beverage	683	1820	216
Gannan Milk Product Factory, Gansu	Beverage	1130	1921	230
Wutai Seabuckthorn Factory, Shanxi	Raw juice	384	500	76
Seabuckthorn Experimental, Shaanxi	Beverage	500	1500	300

Source: Sun Zhenhua et al. 1989

Because of the improved quality of some seabuckthorn drinks, more than 50 varieties have received awards at the provincial level, ministry level, and State level. Some cases in point are given below.

- "Shawikang" beverage, produced by Taiyuan Integrated Food Factory, was selected as the designated beverage for the Chinese Physical and Cultural Delegation to the Olympic Games in Seoul, 1988.
- "Zhonghua Seabuckthorn Aerated Wine", made at Zhuolu General Distillery, Heibei, was awarded prizes 10 times in national competitions.
- "Seabuckthorn Fresh Juice", from Beijing Lifu Seabuckthorn Company, was given an award for being among the Ten Best Sport Beverages in the national selection in 1989.
- "Jianlibao" seabuckthorn sport beverage, made by the Jianlibao Group Corporation, Guangdong, was selected as the beverage for the Chinese Physical and Cultural Delegation to the Asian Games in Beijing, in 1990.

Seabuckthorn's multipurpose function and its various products have drawn the attention of many foreign businessmen from Europe, America, Japan, the former USSR, South Korea, Singapore, Taiwan, and Hong Kong. On the one hand, they purchase seabuckthorn raw juice, oil, cosmetics, wines, and other products from China (for example, until 1989, Shanxi Province exported various products worth up to US$ 400,000); on the other hand, foreign businessmen come to China to invest in joint ventures for seabuckthorn production. For example, the Tianjin Yousheng Food Corporation, a Chinese-American joint venture, produced "Boshang" Seabuckthorn Drink and the Beijing Lifu Seabuckthorn Group Corporation joined with the Japanese Shajian Corporation and produced Seabuckthorn Tea Bags and Seabuckthorn Medicated Diets.

Use in Medicinal Industries

Modern analysis and testing methods are becoming better and approaching perfection day by day. Through this the medical value of seabuckthorn is being constantly revealed. In 1966, The Pharmacologic Committee of the Ministry of Public Health of the former USSR approved of seabuckthorn oil for clinical use in hospitals. Now some ten varieties of seabuckthorn drugs have been developed. These drugs are available in different forms, e.g., liquids, powders, plasters, films, pastes, pills, liniments, suppositories, aerosols, etc and sometimes in compound state. They may be used externally or can be taken orally. These drugs can be used for treating oral mucositis, rectum mucositis, vaginal mucositis, cervical erosion, radiation damage, burns, scalds, duodenal ulcers, gastric ulcers, chilblains, skin-ulcers caused by malnutrition, and other skin damages.

The most important pharmacological functions of seabuckthorn oil, as discovered by the scientists of the former USSR, can be summarised as diminishing inflammation, disinfecting bacteria, relieving pain, and promoting regeneration of tissues; this implies that seabuckthorn oil can also be used for skin grafting, cosmetology, and operational treatment of corneal wounds. Using local seabuckthorn oil, the Organic Chemistry Institute, Kirghizia Academia of Sciences, developed the new drugs "Kiplekos", "Kipkos", and "Dawughir" that enhance the endurance capacities of human beings.

In the former USSR, the demand from medicinal industries is so large that the currently available output of seabuckthorn oil cannot meet the increasing requests. Seabuckthorn oil, therefore, becomes a very rare product, and the price of raw materials and oil goes up quickly. In 1980 the purchasing price of the fruit was 0.9 Rbl./kg but in 1986 it went upto 1.24 Rbl./kg. In 1986 the purchasing price of seabuckthorn oil was 40 Rbl./kg but in 1989 it went up to 67.4 Rbl./kg.

During the past 40 years, Biysk Vitamin Factory, the biggest seabuckthorn oil factory in the former USSR, doubled its output again and again. In 1989 the output reached 125 tons, and it was bottled into 25 million bottles (each bottle contains 50ml). From this output, one in every 250 people could get one bottle, but this only met one-sixth of the demand (750 tons) of the Ministry of Public Health of the former USSR. If the output of Biysk is added to the output (65 tons) of Ulan-Ude Alcohol Drink Factory, and the output of other smaller factories, there still would be a lack of oil to the tune of at least 300 tons in the former USSR. Some experts consider that the currently available seabuckthorn oil and its series of drugs can only meet one-tenth of the general demand in the country. Because these drugs have evident functions in health protection, they also attract people who are not patients. It is difficult to find seabuckthorn oil and its products in the shops; these products are only provided to people who hold a certificate which is issued by the State Medicine Bureau.

In the free markets of the former USSR, sometimes seabuckthorn oil can be found but the price is double that of the State price (6.74 Rbl./100ml).

It is reported that among the 50 varieties of food products of the Soviet Astronauts, a number of them were made of seabuckthorn oil. In recent years, Soviet scientists achieved significant progress by discovering that, like the fruit, the tender branches and leaves of seabuckthorn also contain some bioactive substances. On the basis of this discovery, Biysk Vitamin Factory extracted some oil from the branches and leaves. It is said that cosmetologists are very interested in this kind of oil.

The largest seabuckthorn plantation is located in Guskhrustalnyy, Viladimir State, in the European part of the former USSR. On this plantation, there is a processing factory that extracts oil from tender branches and leaves. This kind of oil is called seabuckthorn cream and is distinct from the fruit oil.

All the seabuckthorn cream is provided to a pharmaceutical factory in Riga City where it is processed into an ointment for treating burns. Because seabuckthorn oil is very profitable, many Soviet State farms, such as the Siberian State Farm, Flora State Farm, and Gusihrustali Seabuckthorn Farm, established their own workshops to extract seabuckthorn oil. For example, in Surtov State Farm, located in the Mali Autonomous Republic, there is a workshop for extracting seabuckthorn oil. The workshop is equipped with some machines developed by the Soviet Institute of Pharmaceutical Chemistry and Technology and it is run by two mechanics and one laboratory technician. They extract oil by using freon as a solution. The oil quality has been tested and it is of medical standard. Details regarding some seabuckthorn drugs sold in the former USSR are discussed below.

"Gibozoli" Seabuckthorn Oil Aerosol. The registered number of the drug is 84-677-5. It was given approval by the Administration and Extension Bureau for New Drugs and New Medical Apparatus and Instruments, the Ministry of Public Health of the former USSR, on February 12, 1986.

Gibozoli is a foam liquid contained in a glass bottle. The main ingredients are seabuckthorn oil, methyluracil, and sodium sulfanamide. The net weight is 57gm and it is valid for two years. It is made at Biysk Vitamin Factory. Each bottle costs 2.40 Rbl.

This drug can be used for treating oral mucositis, rectum mucositis, and vaginal mucositis.

"Olazoli" Seabuckthorn Oil Aerosol. The registered number of the drug is 81-610-4. It was given approval by the Administration and Extension Bureau for New Drugs and New Medical Apparatus and Instruments and the Pharmacological Committee, the Ministry of Public Health of the former USSR, on 8 June, 1981.

Olazoli is a compound drug in which the main effective ingredients are seabuckthorn oil, P-aminobenzoic acid, ethyl ester, elvomycin, and boric acid. The net weight is 60g and it is valid for one year. It is made at Biysk Vitamin Factory. Each bottle costs 2.0 Rbl.

This drug can be used for treating wound infections, burns, malnutrition, ulcers, eczema caused by bacteria, scab-dermatitis, and for skin-grafting.

Ointment for Burns. The registered number of the drug promulgated by the Ministry of Public Health of the former USSR is 18-21-81. The drug is an emulation contained in a plastic bag. The main ingredient is seabuckthorn cream which is extracted from tender branches and leaves. It is made at a pharmaceutical factory in Riga, the capital of Latvia. Each bag contains 20g and costs 1.10 Rbl.

Seabuckthorn Glue Plate. The registered number of the drug is 83-914-7. It is a kind of aseptic glue plate with an area of 5x5 cm. Every 100g of dried substance contains 99g of collagen and 1gm of seabuckthorn oil. This drug should be maintained in a dry, cool, and dark place. The validity is for 2 years. It is made at Biysk Vitamin Factory. Ten pieces of glue plate are contained in one plastic bag which costs 2 Rbl. The drug is mainly used for curing burns.

Seabuckthorn Fruit Oil and Leaf Oil. The registered number of the drug is 87-673-4. Usually, the oil is kept in a bottle. The temperature of the storage place should be less than 10°C. The drug is characterised by a high content of carotenoid (more than 130mg/100g). It is made at Biysk Vitamin Factory and on the Siberian State Farm. Every 100ml costs 6.10 Rbl. and the validity is for one year.

Seabuckthorn Oil. The registered number of the drug is 71-273-10. In this drug the carotenoid cannot be less than 180mg/100g. It is also preserved in a bottle and the temperature of the storage place should not be higher than 10°C. Every 100ml of the oil costs 6.74 Rbl., but it is only

sold on doctor's prescription. It is made at Biysk Vitamin Factory, the Beverage without Alcohol Factory in Ulan-Ude, the former Buryat Autonomous Republic, and at Surtov State Farm of the Mali Autonomous Republic.

Protective Ointment (Hands). The drug contains a universal, atoxic component with a polymerised capacity. When it is spread on the surface of the hand, it forms an invisible, impenetrable protection membrane that can be washed with hot water and soap solution. The drug is scented with pine and peppermint. The drug can be made in three formulas. Formula 1 can be used for protecting the skin from abrasion caused by salt, acids, and alkalis. Formula 3 can be used for protecting the skin from abrasion caused by organic solvent, resin, and paint. Formula 2 synthesises the features of Formula 1 and 3 and has a comprehensive protective function.

The drug can be stored at room temperature. Like common cosmetics, it can prevent the skin of the hand from cracking and enhances the elasticity of the skin. Because this drug contains seabuckthorn oil, it protects the skin. The Ministry of Public Health of the former USSR gave approval for the drug to be used for the purposes mentioned above.

This drug can be used for protecting the skin of the hand from abrasion caused by organic solvents, petroleum products, paints, resin, acids, and alkalis. It has also been proved that this drug is effective in protecting the hands from damage in daily life, for example, house repairs, using daily equipment, fixing cars or trucks, and operating pesticide-spreading machines, and so on. The drug is made in Biysk Vitamin Factory.

"Gipulekos" Seabuckthorn Sweet Pill. This sweet pill was developed jointly by the Institute of Organic Chemistry and the Institute of Biomedicine, Tadzhik Academy of Science. It was given the Soviet State Patent in 1982. The main ingredients (weight percentage) are seabuckthorn juice (24-26%), seabuckthorn fruit skin (18-24%), extraction from walnut shell (4-6%), rose jam (8-12%), starch (4-6%), and sugar (26-42%).

Because the drug contains a series of natural bioactive substances, it can promote digestion and assimilation of food, impel normalisation of the metabolism of cholesterol, activate the process of oxidation and reduction in tissue, consolidate the blood vessel wall, and improve the whole metabolism. The sweet pill is considered to be a broad spectrum tonic and a strong drug (Wu Fuhen, 1991). This is a tonic and a robust drug because it is an enriched mixture with a lot of nutrients and bioactive substances. The following are its basic components:

Vitamin C	2-3%	Flavonoid	0.8%
Organic acids	1-1.2%	Volatile Oil	0.4-0.5%
Fat	5-6%	Pectin	3-4%
Carotene and Caretenoid	10-15mg/100g	Vitamin B_2	5-6mg/100g
Vitamin B_1	0.01mg/100g	Vitamin K	0.5mg/100g
Vitamin B_6	0.015-0.02mg/100g	Quinone	50-55mg/100g
Vitamin E	8-10mg/100g	Amino acids	high quality
Pigment	100mg/100g		

Compared to the former USSR, China's experiences in using seabuckthorn products for medicinal uses are as follows. Although China was one of the earliest countries in the world to use seabuckthorn as a medicinal plant, it was only used in limited regions, e.g., Tibetan and Mongolian doctors used it to treat some common diseases. It had never been considered an important medicinal resource to be studied and used in modern hospitals until the mid-1980s. Since then, a substantial amount of information has been transferred from the former USSR to China. This has encouraged Chinese researchers and doctors to study the biochemistry of seabuckthorn and its clinical practices, and some remarkable progress in research has been made during recent years.

Compared to the long experience of the former USSR in seabuckthorn medicines, China's study and achievements are relatively few. Nevertheless, some products and effective drugs have been developed. They are discussed below.

Seabuckthorn Oil. In 1988, China's first modernised seabuckthorn oil production line was built in Yongshou County, Shanxi Province. This production line is run by Qin Yong Seabuckthorn Corporation, Shaanxi, and it produces 20 tons of seabuckthorn oil, which meets the State standard each year. The oil output of this factory can meet the demands of Chinese markets on the whole, and some of the oil products have been shipped abroad to countries such as Japan, England, Hungary, Singapore, Hongkong, and Taiwan.

Seabuckthorn Flavone Tablet. This drug was developed by the Pharmaceutical Factory of West China Medical University, Chengdu, Sichuan, in 1986. It obtained a permit for production and sale from the Public Health Department of Sichuan Province and the Approval Document Number is (86)-3877.

Seabuckthorn Flavone Tablet is a new drug for the treatment of coronary diseases and it may improve myocardial performance, myocardial ischemia, and remit stenocardia.

The drug is prepared from dry berries of seabuckthorn and its ingredients are isorhamnetin, quercetin, and their glucosides.

Seabuckthorn Sweet Granule. This drug was developed in 1985 by Lanzhou Pharmaceutical Factory, Gansu Province, by adopting traditional Chinese medicinal techniques. Permission was given for production and sale by the Public Health Department of Gansu Province, and the Approval Document Number is (85) - 595-1.

Seabuckthorn Sweet Granule is used to relieve coughing, reduce sputum, help digestion, and promote blood circulation by removing blood stasis. It also may increase the metabolism, build up the physique, and delay the ageing of tissue.

This drug is prepared from the extraction of seabuckthorn fruit and sugar. It is used both in medicines as well as drinks and is well received in both domestic as well as foreign markets, for example, tons of Seabuckthorn Sweet Granules were exported to Europe in 1987.

Seabuckthorn Dried Emulation. This drug was jointly developed in 1990 by Yongshou Pharmaceutical Factory, Shaanxi Province, and the Shaanxi College of Traditional Chinese Medicine. Permission to produce and sell was given by the Public Health Department of Shaanxi Province and the Approval Document Number is (90)-00301.

This drug is prepared from the extraction of fresh seabuckthorn fruit and it contains all bioactive substances. Clinical experiments have shown that the drug can be used for the treatment of blood-deficiency, cardiopathy, coronary diseases, stenocardia, and to reduce blood fat and blood pressure. It may improve the brain function and bring about remission in cases of memory loss.

Use in Cosmetic Industries

More than one hundred kinds of active elements have been identified in various parts of the seabuckthorn plant. Based on its nutrients, many medical studies, testing its effect on the skin, showed that seabuckthorn extracts could effectively improve the micro-circulation of blood capillaries and nourish skin and hair. It was also proved that the extracts can retard peroxidation of the lipide and are better than Vitamin E and Bunge Swallow Wort (*Cynanchum bungei*, a Chinese traditional medicine). After several years of study, many kinds of seabuckthorn cosmetics have been developed and tested in hospitals.

Clinical Effects of Seabuckthorn Cosmetics

The practical efficacy on 350 patients treated in Guangdong Provincial People's Hospital and Guangdong Provincial Institute of Medicine was observed, and the results showed that seabuckthorn beauty cream had positive therapeutic effects on xanthopsis, melanosis, senile skin wrinkles, keratoderma, keratosis, desquamation, senile plaque, palm skin rhagades, xeroderma, face-acne, recurrent dermatitis, chemical corrosin, and ichthyosis, as well as freckles.

It was gratifying to find that seabuckthorn beauty cream could make the tested patients' skin become fair, clear, and delicate. The cases of acne recovered and their pigment changes disappeared soon after using seabuckthorn beauty cream. Several post-partum women found that the large pigment patches on their faces completely disappeared after applying seabuckthorn beauty cream for 1-2 months and the face skin became normal (He Xuejiao et al. 1989).

Clinical experiments made in Shantow Tropical Disease Hospital and the Shanxi Pharmaceutical Research Institute showed that cosmetics containing seabuckthorn extracts can improve metabolism and retard skin maturation. Application of this cosmetic on the skin made the skin smooth and soft. Hair care with this cosmetic had the effect of retarding baldness and improving hair growth.

Out of 537 patients, 88.1 per cent demonstrated that the cosmetic can cure 16 tropical diseases. They are pityriasis sicca, seborrhea sicca, alopesis, prickly heat, summer dermatosis, scabies, impetigo, acne vulgaris, pustule vulgaris, contact allergic reactions, xanthopsis, xeroderma, verruca, and lentigo (Zhong Chongju et al. 1989).

Products of Seabuckthorn Cosmetics

In the international cosmetics' market, there appears to be a striking preference for natural cosmetics, especially those

containing plant compositions. According to investigations carried out in recent years in the departmental stores of some large Chinese cities, cosmetics are the favorite commodities and the volume of business in cosmetics has increased more than in other commodities. Since seabuckthorn oil was proven to contain many bioactive substances that can improve, protect, and nourish human skin and hair, many dozens of new cosmetics based on seabuckthorn oil and flavones have been produced and marketed.

There is no definite statistical figure to show how many seabuckthorn cosmetics are available, but it is very easy to find seabuckthorn cosmetics in any big Chinese city. Some factories built up a remarkable reputation after producing seabuckthorn cosmetics. For example, Datong Daily Chemical Plant, Shanxi Province earns a profit of about 700,000 *yuan* (134,625 US$) annually from selling seabuckthorn cosmetics.

Use of the Leaves and Residues

Nutritional Value of the Leaves

The leaves of seabuckthorn have been proved to contain many nutrients and bioactive substances. Table 11 shows the contents of the nutritive components in the leaves of some species and sub-species of *Hippophae* in China. From Table 11, it can be seen that all species and subspecies are rich in protein. However, the contents are quite different. Among them, *H. rham.*, spp. *gyantsensis* contains the highest amount of protein (22.92%) and fat (96.10%). The lowest contents of protein (11.47%) and fat (3.68%) occur in *H. neurocarpa*. The leaves, of either female or male plants, have similar nutritive compositions (see Table 12). In the natural groves of seabuckthorn, it is often found that the quantity of male plants is larger than female plants. Because male plants do not bear fruit, their leaves and tender branches can be used for forage.

Table 11: The Contents of the Nutritive Components in the Leaves of Some Species of *Hippophae* in China (%)

Species	Altitudes (m)	Occurrence	Crude Protein	Crude Fat	Crude Fibre	Ash	N-Free Extracts
H.rham. ssp. *sinensis*	2700	Xiaojin, Sichuan	16.59	4.41	15.20	9.02	57.78
H. rham. ssp. *yunnanensis*	3200	Zhongdian, Yunnan	19.28	4.36	14.28	5.06	48.26
H. rham. ssp. *turkestanica*	800	Huocheng, Xinjiang	15.18	5.61	17.37	5.10	56.76
H. rham. ssp *gyantsensis*	3700	Zedang, Xizang	22.92	6.10	16.52	6.20	48.36
H. thibetana	3200	Chuona, Xizang	18.79	4.08	16.43	4.57	56.13
H. neurocarpa	3400	Hongyuan, Sichuan	16.44	5.46	16.66	3.36	58.08
H.neurocarpa	3500	Daocheng, Sichuan	11.47	3.68	19.72	3.38	61.30

Source: Lu Rongsen 1991
Note: The content of nutritive components is calculated on the basis of dried substance weight.

Table 12: Comparison of Contents of Nutritive Components between Seabuckthorn and Clover

Plate name	Part Analysed	Crude Protein	Crude Fat	Crude Fibre	Ash	N. Fee Extracts
H. rham. ssp. *sinensis*	Female leaves	17.1	4.6	16.9	5.9	55.7
-do-	Male leaves	16.2	4.2	13.0	4.1	62.5
Trifolium pratensis	Stem+leaves	17.1	3.6	21.5	10.2	47.6
Trifolium repens	Stem+leaves	24.7	2.7	12.5	13.0	47.1

Source: Lu Rongsen 1991 and Shu Jiakai 1983

From Table 12, it can be seen that the content of protein (16.2-17. 1%) in seabuckthorn is almost equal that (17.1%) found in red flower clover (*T. pratensis*) but less than that (24.7%) found in white flower clover (*T.repens*). The fat content (4.2-4.6%) in seabuckthorn leaves is more than (2.7-3.6%) in the above-mentioned species of clover. The conclusion is that seabuckthorn leaves are good for forage. In fact, the farmers in mountain areas often drive their sheep and cows into seabuckthorn bushes to graze. Seabuckthorn leaves promote the growth of livestock and have even helped increase fertility.

Residues of Fruit and Seeds and their Uses

When the fresh fruit is squeezed and juice extracted, a lot of residue remains, and also when the oil is extracted from seeds, a lot of seed residue remains. The residues of both fruit and seeds account for about 20 per cent of the total weight while fresh. These residues are rich in protein, fat, amino acids, Vitamin C, fat-soluble Vitamins A,D,E, carotenoids, flavonoids, micro-elements, sterol, choline, and betaine (Chen Tigong et al. 1988). In order to determine the effects of seabuckthorn leaves and the residues of fruit and seeds on animals and poultry, a series of experiments have been conducted by the Traditional Chinese Veterinary Medicine Institute, Chinese Academy of Agricultural Sciences, Lanzhou, China. The results are discussed below.

1. It has been proven that seabuckthorn leaves and the residues of fruit and seeds used as a supplementary feed can promote the growth of animals and poultry and increase their productivity. For example, feeding on supplementary seabuckthorn leaves, pigs increased their weight by 9.38-21.27 per cent and milch goats raised their output of milk by 6.24-6.88 per cent, and by feeding on supplementary seabuckthorn leaves and the residues of fruit and seeds, chickens enhanced their egg laying rate by 8.7-13.3 per cent and their laying output by 24.9-28.7 per cent. In addition, the content of carotene óbviously increased and the content of cholesterol decreased in chickens and broiler chicks increased in weight by 3.9-5.7 per cent.

2. Toxicological experiments have proven that the maximum tolerant dose is 50,000 mg/kg when mice are given extracted liquid from seabuckthorn leaves and residues of fruit and seeds. It seems that seabuckthorn supplementary additives are non-toxic. It has also been proven that there is no accumulated toxicity, no carcinogenesis, and no induced tumours observed over a long period of feeding and that these supplementary additives do not affect the normal propagation of animals and no deformation of embryos has been seen. On the contrary, long-term feeding with these supplementary additives may promote the growth and development of immune organisms, enhance immune activity, and increase the disease-resistivity of animals (Liu Xuchuan et al. 1989).

Seabuckthorn as a Food Additive

The pigment of seabuckthorn is widely used as food additive. Because many synthetic chemical pigments have been proved to be harmful to the health of human beings, natural pigments are preferred. Seabuckthorn fruit contains rich yellow substances. However, until recent years, the fruit residue was often thrown away as waste. A food pigment called "Seabuckthorn Yellow" has been developed by the Institute of Biophysics, Academia Sinica. At present, the productive capacity of the powdered pigment is over several tons per year. Seabuckthorn Yellow consists of flavones (usually more than 95%), carotene, and Vitamin E. Its physicochemical properties are given below.

1. Appearance: brown yellow or orange yellow powder.

2. Solubility: it is readily soluble in alcohol, either, chloroform, acetone, petroleum, oil, etc.

3. Colour Value: $E \overset{1\%}{\underset{1cm}{-----}} 445\ nm > 20$

4. Heat Stability: its orange yellow colour is quite stable. It can tolerate 220^0 C for 20 minutes in powder and 100^o C for 2 hours in solution.

5. Light Stability: its orange-yellow colour is quite stable.

6. Effect of pH: in the range of pH 3.6-9.3, its orange yellow colour was effected slightly.

7. Effects of Metallic Ions, Oxidizing Agents, and Reducing Agents: F^{+++}, Ca^{++}, and Vitamin C had greater effects (absorptivity decrements were about ½ respectively) and Cu^{++}, Mg^{++}, Na^{+} and H_2O_2 had merely slight effects (Liu Duohua et al. 1989).

Seabuckthorn Use in Other Countries

Europe

Finland. Historically, there were large areas of natural seabuckthorn in Finland. Because of the extension of the forests, seabuckthorn growth moved to the seashore. Now natural forests are only distributed along the Baltic Coast and the Aland Islands. According to Rousi (1971), this seabuckthorn belongs to the species *Hippophae rhamnoides L.*, subsp. *rhamnoides* which can grow well and bear fruit in soil containing 0.4-0.5 per cent of salt. There are two main institutions in charge of the development of seabuckthorn. One is the Joensu Research Station of the Finnish Forestry Research Institute, which introduces and domesticates wild seabuckthorn plants and establishes vegetative plantations introduced from the former USSR. The other is the Institute of Horticulture of the Agricultural Research Centre, which is now spreading new varieties that are expected to adapt to Finnish conditions. This institute did introduce some cold-resistant varieties from the former USSR, but these died under conditions of -33°C in winter time. The indigenous varieties are still surviving and have been bearing fruit for 18 years (Junnila et al. 1989).

Though there is a tradition of making jams and juices from seabuckthorn fruit on the Finnish coast, along the Gulf of Bothnia, the modern industrial processing of seabuckthorn in Finland is in its early stages. However, there is a seabuckthorn wine factory which is located at Kokkola in the Gulf of Bothnia. The factory produces a yellow wine with a typical seabuckthorn smell, containing 11 per cent of alcohol, and this is marketed in Finland and abroad.

Sweden. Seabuckthorn is also distributed on the Swedish coast along the Gulf of Bothnia and along the west coast of Sweden. Seabuckthorn, as a forest resource, is used commercially in Sweden. There are also some institutes engaged in studying seabuckthorn. For example, the Department of Horticultural Plant Breeding of the Swedish University of Agricultural Sciences now has a programme that aims to introduce some minor crops as commercial berry crops in Sweden. Through this programme some species and subspecies of seabuckthorn have been introduced into Sweden, including plant materials originating in the former Soviet Union. It is expected that new varieties suitable to Swedish conditions will be propagated in future.

Poland. Natural Seabuckthorn forest is found on the Baltic Coast of Poland. However, there are some possibilities for its cultivation in other difficult regions, for example, on wastelands, on post-industrial dumps, and even in highly industrialised towns.

Kluczynski (1989), of the Institute of Biology, University of Szezecin, Poland, studied the effects of seabuckthorn cultivated on post-industrial wastelands and analysed the results: seabuckthorn can grow well on the sediments from energised ashes of pit-coal; the dump of brown-coal, cap-rock, and post-flotation zinc sand, but it failed on the sediment from brown-coal ashes and on the slope of a pit sand mine.

Furdyna and Sendal (1973) compared the results of waste-dump investigation in the Upper Silesian Industrial Region, Poland. They experimented with afforestation on 65 different dumps, 1,505 ha in area, with various species such as *Betula pendum*, *Fraxinus excelsior*, *Robinia pseudoacacia*, *Alnus glutinosa*, *Quercus rubra*, *Populus sp.*, *Acer sp.*, *Rosa sp.*, *Padus serotina*, and *Sorbus aucaparia*. All species failed to survive, but seabuckthorn was found growing on 3 dumps of barren rock retrieved from the deep mining of pit coal (total area 8.5 hectares).

Hungary. Seabuckthorn cultivation in Hungary is in the early stages and is still on a small scale. Following the excellent results achieved from the breeding of Altaic Seabuckthorn in the Siberian Fruit Research Institute in the former Soviet Union, Hungary introduced 9 cultivars with large fruits, rich in bioactive substances, and without thorns for a cultivation experiment in 1984. They established more than 10 ha for trial. The first yield appeared in 1987. The tendency of yields was measured and the quality of fruit was compared with those of indigenous varieties as well. The final results are still pending. In Hungary,the aluminum industry is of great importance. As a by-product, red mud, sometimes called bauxite residue, is obtained in mass. The red mud consists mainly of oxides of metals without any humus content. The red mud impoundment often causes serious pollution problems. After several years of experiment, it appears that seabuckthorn is a suitable plant for reclamation of the red mud impoundment. Seabuckthorn not only survived on the red mud but also bore good fruit (Balink et al. 1989).

Asia

India. Seabuckthorn is widely distributed throughout the Indian Himalayas. There are three species and subspecies scattered at different altitudes and throughout different

climatic zones. *Hippophae rhamnoides* L., Subsp. *turkestanica* (in Hindi, it is called *Dhurchuk*) is mainly found in the Punjab, Ladakh, Lahul, and other areas. *Hippophae thibetana* is usually found at high altitudes (more than 4,000 masl) in Kinnaur, Lahul, Kumaon, and so on. *Hippophae salicifolia* (in Hindi, it is called *Chuma, Kalabis*) commonly occurs in the temperate Himalayas at altitudes of about 1,500-3,000 m, for example, in Kumaon, Kinuaur, and Lahul and Spiti.

The people who live in the Indian Himalayas began to use the fruit of seabuckthorn as a food and medicine a long time ago. Because the fruit is too sour, it is often made into a jelly with sugar. A syrup prepared from the fruit is used for lung complaints. A decoction is used for cutaneous eruption. Indian scientists, Ambaye et al. (1962), found a tumour-inhibiting activity in the bark of *H.Salicifolia* and it has given promising results as a cure for certain types of cancer.

In the high mountain areas, local people grow seabuckthorn for hedges and fences. In some places, natural seabuckthorn forests are used for fuelwood and for making charcoal. However, seabuckthorn has not yet been cultivated for commercial purposes in India.

Pakistan. One subspecies (*H. rhamnoides L., subsp. turkestanica*) is found in the northern part of Pakistan. Normally it is spread throughout the Karakorum Ranges at altitudes of 2,000-4,200 m (Chitral and Gilgit). There are no reports available on local uses of seabuckthorn.

Afghanistan. Because of the similarity in natural conditions with Pakistan, Afghanistan has the same subspecies, e.g., *H. rhamnoides* L., subsp. *Turkestanica*, and this is distributed throughout a wide range of mountains at altitudes of 2,300-3,000 m, including Bamian, Kabul, Parvan, Gulbahar, and Nuristan. It is reported that the seabuckthorn bush is sometimes used for hedges around fields and as fuelwood as well.

Nepal. Two species (*H.thibetana* and *H. salicifolia*) are identified in the high mountain areas of Nepal. Relatively, *H. thibetana* is limited to a small area, because the population of the species only occurs at 4,000 m and above. *H. salifcifolia* has a wider distribution, from the Far Western Region to the Eastern Region, at altitudes of about 2,000 m - 3,700 m.

Seabuckthorn (in the Sherpa language, it is called *Khurpu*) has long been used in various ways in Nepal. Its fruit is edible and sometimes made into a chutney or a pickle. Because the fruit is rich in acidic juices, it is often used for making vinegar in mountain homes. Some farmers grow seabuckthorn as a fence around the house or fields in order to keep the cattle and sheep away.

Bhutan. Seabuckthorn distribution in Bhutan is similar to Nepal. *H. thibetana* is found at high altitudes, ranging from 4,000 to 5,000 m, and *H. salicifolia* is located in the Trans-Himalayas at altitudes of 1,500 - 3,500 m.

For a long time, the Bhutanese have used the fruit of *H. thibetana* as a medicine for stomach ache and the fruit of *H. salicifolia* is used for polishing gold and silver.

IV. A Plant for Upgrading Marginal Mountain Lands

For fragile and marginal lands in mountain regions, the environmental gains of seabuckthorn reflected through resource upgrading, i.e., building/binding of soil on steep slopes and conservation of moisture for productive use, may far exceed the commercial benefits discussed in the preceding section. The root system, rapid prolification, nitrogen fixation, adaptation to harsh environmental conditions, and other attributes of this plant discussed earlier, amply equip seabuckthorn to play a conservation role in the fragile and marginal mountain lands. We discuss this by briefly summarising the Chinese experience. The case of the Loess Plateau is discussed in detail.

Use in Controlling Loss of Water and Soil

Harsh Situation

China is a country that lacks sufficient forest area. Its forest coverage is only 12 per cent of its total area, and the per capita of timber is 0.02 m^3. In China, 60 per cent of 800 million farmers experience a shortage of firewood for 3 to 5 months each year. In northern and north-western China, particularly,there is less vegetation cover and the land surface is always exposed. Rainfall is below 400 to 500 mm and it is extremely uneven. Ecological conditions are so poor that soil erosion persists throughout. On the Loess Plateau, for example, the soil erosion modulus generally exceeds 5,000 tons/km^2/year, and in some areas, it reaches 30,000 tons/km^2/year (Li Min et al. 1989). The sediments carried each year by the Yellow River to the lower reaches is 1.6 billion tons, mostly from the Loess Plateau.

Severe loss of soil and water has devastating effects on farming, forestry, stock-breeding, and on the ecology and environment of the area concerned. It also influences use of water, land, and mineral resources. Huge quantities of sediment deposited in the lower reaches have rendered the river "suspended" above the adjacent land surface, seriously menacing life and increasing poverty in the North China Plains. To control soil erosion is the most urgent task in this region. Seabuckthorn has a lot of advantageous characteristics over other trees and shrubs and, since the rainfall in this region cannot meet the requirements for tree afforestation, but can for seabuckthorn and other shrub afforestation, it has often been chosen as a pioneer species in afforestation. Since the 1940s, seabuckthorn has been cultivated as the plant for soil and water conservation in northern and north-western China and much knowledge and experience have been accumulated regarding it. The local inhabitants are now mobilised to make good use of the advantages of growing seabuckthorn on a large scale to conserve water and hold soil so as to improve the ecology and environment in this region. This has become an important task and much attention has been paid to this by the Chinese Government.

Ecological Benefits of Seabuckthorn Forest

One of the most successful regions that has used seabuckthorn as a water and soil control plant is the Western Liaoning Province which is located in northeastern China. With a total area of 50,111 sq.km., of which the mountain lands account for over 70 per cent, the vegetation cover rate is 15 to 30 per cent, and the forest cover rate is only 12 to 15 per cent. The climate here falls into the semi-arid and semi-humid climate ranges. The annual rainfall is 350-600 mm, of which 70 per cent is concentrated in July and August. The existing eroded area is 33,188 sq.km. and the modules of erosion are 2,500-8,000 tons/km^2/year. Therefore, the environment is seriously imbalanced and natural disasters such as drought, sandstone, and floods occur frequently. These severely hamper the development of agriculture, forestry, and animal husbandry. As a result, this region has become one of the ten poverty-ridden regions of China.

In order to bring soil erosion under permanent control, to improve the environment, and to promote agricultural development, several species of tree and shrub were planted in this region. Among them seabuckthorn had the strongest competitive ability both in pure and mixed forests. Hence, it was sown over large areas and soon several seabuckthorn forests were established. Since 1984, a lot of information

about the integrated use of seabuckthorn in different fields was accumulated, the single ecological benefit of seabuckthorn also gradually expanded into economic returns.

Thereby seabuckthorn planting reached a climax. The seabuckthorn forest area was 266.77 sq.km. in 1984, but it reached 1,133.33 sq.km. in 1988, of which the mixed seabuckthorn forest accounted for 30 per cent. The artificial seabuckthorn forest area in western Liaoning has become the largest one in the country and Jianping County has the largest seabuckthorn forest area in this region. The total area of seabuckthorn plantation in Jianping County has reached 520 sq.km., of which 400 sq.km. has borne fruit with an annual output of 15,000 tons.

The Effects on Water Retention, Soil Conservation, Wind Control, Sand Fixation, and River Bank Protection. The growth of a five year old seabuckthorn plant can reach up to 1.69 m with 1.7 m of crown diameter. When it occurs in pure stands the canopy density can reach 0.9 m. This canopy layer plays an important role in reducing soil erosion caused by the kinetic energy of rainfall and intercepts much rainfall. Based on the determination of a five year old seabuckthorn forest in Luofu Gully, Jianping County, the interception rate of rainfall by the canopy was calculated at 8.5-49.0 per cent. In a ten year old seabuckthorn forest, the litter thickness was 1-3 cm, capable of absorbing 1.8-2.2mm of rainfall. Therefore, the canopy and litter can regulate surface runoff and increase the soil infiltration capacity effectively. Judging by the measurements taken of runoff plots in this forest, 94.20 per cent of runoff and 77.63 per cent of sediment reduction were obtained against those in waste mountain lands which were taken as the control. In seven year old seabuckthorn forests, 99.6 per cent of runoff and 96.6 per cent of sediment reduction against those in the control were obtained (see Table 13).

Table 13: Comparison of Runoff and Soil Loss Observed between Waste Mountain Land and Seabuckthorn Forest Land

Items	Waste Mountain Land	Seabuckthorn Forest Land
Plant cover (%)	25	90
Annual Rainfall (mm)	380.6	380.6
Runoff (m^3/ha^{-1}/annum)	1672.20	7.49
Soil loss (kg/ha^{-1}/annum)	314.25	10.80
Runoff reduced (%)	-	99.6
Soil loss reduced (%)	-	96.6

Source: Li Quanzhong et al. 1989

The artificial seabuckthorn forest built along river banks had remarkable effects on wind control and sand-fixation. For example, the windbreak provided by seabuckthorn built along the banks of the Laohahe River, Jainping County, prevented sand drifts and formed a natural sand wall to protect the river banks and fields of crops.

In Xiangyang and Taiping townships, seabuckthorn wind-breaks intercepted the sand drifts reaching 13,708-23,370 m^3/km^2/ year, thus reducing the sand dust in the air. Poplar forests mixed with seabuckthorn had better protective effects than pure poplar forests. The thickness of the captured sand by a nineteen year old mixed forest increased 33.3 per cent compared to pure forests of the same age. The thickness of the deposited soil layer in mixed forests increased 89.3 per cent compared to that of pure forests (see Table 14).

The Effects on Soil Fertility. Seabuckthorn plants have a dense crown and a strong, well-developed root system. A five year old seabuckthorn plant has a root system with an extension of 4.5m and a tap root with a depth of 2.5m. The total weight of the root system is 0.777 kg/m^2. The seabuckthorn plant produces a great deal of biomass both above and underground through its metabolism. This biomass is transformed into organic and mineral materials by the activities of microbes in the soil. All organic and mineral materials can improve the soil's physical and chemical properties and raise soil fertility (see Table 15).

Table 14: Comparison of Amounts of Soil Deposited in Pure Poplar Forests and in Poplar and Seabuckthorn Mixed Forests in the Laohahe River

Items	Pure Poplar Forest	Poplar and Seabuckthorn Mixed Forest
Forest Age (year)	19	19
Movable Sand Thickness(cm)	62.5	83.7
Increased (%)	-	33.9
Deposited Soil Thickness (cm)	10.1	100.3
Increased (%)	-	893.1

Source: Li Quanzhong et al. 1989

Table 15: The Physical and Chemical Properties of Soils on Different Types of Land*

	Waste Mountain Land	Pure Chinese Pine Forest Land	Pure Seabuck-thorn Forest Land
Forest age	-	5	5
Canopy density	-	0.5	0.8
Total nitrogen (%)	0.060	0.067	0.074
Total phosphorus (%)	0.055	0.096	0.064
Organic matter (%)	0.952	1.092	1.300
Bulk density ($9cm^{-3}$)	1.43	1.32	1.29
Porosity (%)	47.04	51.11	52.22

Source: Li Quangzhong et al. 1989

* Sampling depth is 40cm.

Table 15 shows that the total nitrogen, the total phosphorus, and the organic matter contents in pure seabuckthorn forests are respectively 0.014 per cent, 0.009 per cent, and 0.384 per cent; more than the amounts contained in waste mountain land. The soil bulk density is 0.14 g/cm^3 less and the soil porosity of seabuckthorn forest land is 5.18 per cent higher than waste mountain land.

The Role of Seabuckthorn in Mixed Forests. For a long time, Chinese pine (*Pinus tabulaeformis*) and poplar (*Populus simonii*) were used for afforestation in western Liaoning. It was proved that pure Chinese pine forests and pure poplar forests were low yielding forests. When the poplar or the Chinese pine were mixed with seabuckthorn, both grew much better than pure forests. For example, based on the survey of a 23 year old seabuckthorn and poplar mixed forest, the average height of poplars in mixed forest was found to be 4 times higher than in pure poplar forests, and the average chest diameter was 3.75 times larger (see Table 16).

Table 16: Comparison of Seabuckthorn, Poplar Mixed Forest, and Pure Poplar Forest

Growing Diameter Place	Type of Forest	Age of Tree	Sample Numbers	Height (m)	Mean Chest (cm)
Middle Slopes	Poplar mixed with seabuckthorn	23	30	6.5	9.0
Lower Slopes	Poplar only	23	30	2.7	2.4

Source: Li Quangzhong et al. 1989

This result is particularly due to the contribution of seabuckthorn to the improvements of the soil moisture and soil fertility. For example, during the growing season from April to September, it was found that soil moisture in the 0.20cm soil layer of mixed forest was 0.2-1.7 per cent more than that of pure poplar forest. The nitrogen content of the cultivated layer (0-20 cm) and the organic matter content in the mixed forest increased by 11.5 per cent and 26.6 per cent respectively (see Table 17).

Seabuckthorn not only increased the nitrogen content of the soil but also improved the nitrogen level in the plant. After careful tests of plant organs, it was found that the total amount of nitrogen in the leaves of poplar in the mixed forest increased by 33.63 per cent compared to leaves in the pure poplar forest. This indicates that seabuckthorn can promote better growth of other trees and that it is a desirable accompanying shrub for plantation in the mixed forests of semi-arid regions.

Table 17: Comparison of the Total Nitrogen and Organic Matter Contents of Pure Poplar Forests and Poplar and Seabuckthorn Mixed Forests

Soil Profile Horizons (cm)	Total Nitrogen (%)			Organic Matter (%)		
	Pure Forest	Mixed Forest	Increase	Pure Forest	Mixed Forest	Increase
0-10	0.0848	0.0953	0.0105	1.520	1.943	0.421
11-20	0.0673	0.0680	0.0070	1.070	1.356	0.286
21-30	0.0580	0.0592	0.0012	1.120	1.220	0.100
31-54	0.0545	0.0555	0.0010	-	-	-

Source: Li Quangzhong et al. 1989

Example of the Loess Plateau, China

The Loess Plateau covers an area of about 600,000 sq.km. and is located in Northern China. The altitude of most parts of it is between 1,000-2,000 masl and the climate is semi-arid to semi-humid. The annual rainfall ranges between 400mm to 600mm, with a large annual variation. There is low vegetation cover, and the percentage of natural forests is only 4.4 per cent. Poor natural conditions and primitive production methods have caused it to be one of the poorest areas of China and lack of fuel, animal feed, and fertiliser are the problems that many districts here have to face.

General View of Water and Soil Loss on the Loess Plateau

The eroded area of the Loess Plateau is estimated to be 430,000 sq.km. (it is almost equal to the area of Iraq or 3 times that of Nepal), and the total annual surface soil loss amounts to 1,600 million tons. Calculations revealed that the fertility loss from the soil exceeded the total chemical fertiliser output produced in the entire country in 1973. Downstream from the Yellow River, the annual accumulation of sediment averages 400 million tons, causing the river bed to rise about 10cm annually. This not only endangers the life and property of the people but also compels the Government to spend vast sums of money in strengthening and increasing the height of the embankment.

Since the 1950s, organised control over soil erosion on the Loess Plateau has been carried out and about 100,000 sq.km. of eroded area have been primarily improved. Thus more than 200 million tons/year of sediment washed down into the Yellow River have been reduced. Among the various control measures, biological measures are predominantly used and have been adopted in 64 per cent of the total area controlled. Among the areas using biological measures, soil and water conservation forests have been established on more than 70 per cent of the area.

For many years, because of the irrational selection of tree species; irrational decisions regarding the location of afforestation; and a variety of other reasons, the survival rate, preservation, and growth of the forests have been unsatisfactory. Therefore, one important subject of research work relating to soil and water conservation in the Loess Plateau is the identification of appropriate tree species and the location of suitable afforestation areas.

After many years of investigation and study, it was found that the local species of seabuckthorn has wide ecological adaptations. It is distributed extensively throughout grasslands, forest-grasslands, and deciduous forest zones of the Loess Plateau, especially on the mountains and hills of the forest grassland zone.

As described earlier, seabuckthorn has many special characteristics that cannot be found in other trees; it can fix nitrogen, improve soil fertility, has a strong ability to sprout from its roots, resulting in individual as well as community plants at a rapid rate, and it can accumulate more biomass in a short period, thus forming dense woods. Table 18 gives a comparison of the biomass accumulation of seabuckthorn and other shrubs on the Loess Plateau.

Table 18: Comparison of the Biomass Accumulation of Seabuckthorn and Other Shrubs on the Loess Plateau

(10,000 kg/ha)

Species	Soil	West Shaanxi		East Gansu	
		Age (years)	Biomass (fresh)	Age (years)	Biomass (dried)
Seabuckthorn	red	15	1.98	9	1.69
Caragana korshinskii	red	15	1.39	6	0.79
Rosa xanthina	red	15	1.78	-	-
Vilex chinensis	red	20	0.39	-	-
Amorpha fruticosa	red	20	0.83	6	0.45

Source: Li Min et al. 1989

Investigations showed that a three-year old seabuckthorn plant can sprout up to 10 turions and a five-year old plant up to 51 stems. On one abandoned wasteland, seabuckthorn forests expanded their borders by 2m or so each year.

Seabuckthorn plants can multiply to form dense, bushy woods over a short period of time and the bushy woods intercept rainfall and protect the soil from erosion. It is reported that in Youyu County, Shanxi Province, 74km of seabuckthorn forest planted on the banks of the Changtouhe River protected the river banks, and the sediment discharged into the Yellow River decreased by 3-5 million tons each year (Li Min et al. 1989).

Seabuckthorn has long been known as a soil and water conservation plant. Why does it now play an even more important role in harnessing the Loess Plateau? A reasonable explanation is that the implementation of any project should mobilise the people (especially farmers) to participate in the project. Before realising the economic value of seabuckthorn, farmers did not care about afforestation because they did not get direct cash income. Now, as the comprehensive benefits have become visible, the farmers have begun to accept this plant. To sum up, seabuckthorn has a high economic value; from each hectare of seabuckthorn, 4,500 kg/year of dry firewood and 1,500 kg/year of leaves, with high nutritive value, are produced. Seabuckthorn also enhances soil fertility by fixing nitrogen, and its fruit is used in the food, medicine, and cosmetic industries. In recent years (1986-1988), extensive exploitation and use of seabuckthorn resources have been carried out on the Loess Plateau. The production value of

seabuckthorn fruit-processing has reached more than 100 million *yuan* (21.2 million US$) altogether, and the products have been offered to both domestic as well as international markets. Therefore, popularising seabuckthorn in poor areas like the Loess Plateau, where fuel, feed, and fertilizer are lacking, has a lot of significance.

Concrete Results and the Long-term Programme

According to statistics, during the period 1986-1989, 53.3 thousand hectares of land were planted annually with seabuckthorn and a total of 213.0 thousand hectares was established on the Loess Plateau. Because seabuckthorn can survive more easily than other trees and bushes, the area of seabuckthorn forest accounted for more than 10 per cent/year of the total forest area treated for water and soil conservation in the region.

To take a case in point, Wugouxian of Zhangyaan County, Gansu Province, is located in the hill and gully area of the Loess Plateau. It has an annual precipitation of 460mm and is one of the poorest areas. During the 30 years before 1982, many tree species, such as apricot (*Prunus armeniaca* var. *ansu Maxim*), poplar (*Populus davidiana*), willow (*Salix matsudasa*), sophora (*Sophora japonica*), elm (*Ulmus laevis*), were tried and the total reforested area reached 2,333 ha. Because the natural condition in the area was very poor and not suitable for these species, only 400 ha of forest, accounting for 17 per cent of the total area, remained. Even those remaining trees did not do well and looked small and weak. From 1983 onwards, the farmers began to plant seabuckthorn on a large scale. With the guidance and help of the local government, by 1988, they planted about 20 million saplings which covered 4,000 ha of mountain slope. More than 80 per cent of the seabuckthorn forest survived and more than 27 per cent of the total area in this township was covered by this forest. The per capita area of seabuckthorn forest was about 0.3 ha and this provided the farmers with enough fodder and firewood.

Yike Zhau in Inner Mongolia is situated towards the edge of the Mu Us Desert. In the total area of 80 thousand sq.km., 47 thousand sq.km., accounting for 58.8 per cent of the total area, are prone to severe water and soil losses. Each year about 0.19 billion tons of mud and sand are washed away from this area into the Yellow River, out of which about 0.15 billion tons are arenite. The modules of soil erosion reach 15,000-30,000 tons/km^2/year. Because most of this area geologically consists of arenites that are characterised by their loose structure, easily breakable by water, and covered with sparse vegetation, when the downpour comes, this kind of arenaceous land quickly disintegrates. Surface soil and water rush down swiftly and many gullies are left. Therefore, the local people call this area the "Valley of Death" and the "area of maximum water and soil loss".

From 1986 onwards, under the leadership and financial support of the Conservation Committee of the Yellow River, the local officers and farmers have jointly worked on the trial, demonstration, and extension of seabuckthorn. Within 5 years, more than 6,666 ha of seabuckthorn forest were established in this area. Now the four-year old seabuckthorn saplings have grown well, reached up to 2m in height, and have begun to bear fruit. Because of the massively sprouting turion seedlings, the canopy density of seabuckthorn forest has exceeded 90 per cent of the planted area on the shady and semi-shady slopes where there is more moisture.

In areas with an altitude of 1,500m, more than 600 ha of mixed forest, consisting of Chinese pine, apricots, and seabuckthorn, have been established. Apparently because seabuckthorn provides more moisture and nitrogen, Chinese pine trees grow much better in mixed rather than in pure forests.

On the Loess Plateau, most parts of the forest-grassland zone and a part of the grassland zone are the areas where extremely severe soil and water loss occur. According to the divisional forest plan of China, the afforestation here, because of moisture limitations, should be carried out with shrubs as the principal species. Seabuckthorn, as a native shrub, has characteristics that have advantages over other shrubs, e.g., it grows faster, it helps soil and water conservation, gives more significant economic benefits, and is more readily accepted by the people.

The total area of this region is about 160,000 sq.km. According to the divisional plan of the Ministry of Forestry of China, the forest cover rate of this region should be 40-50 per cent. Of this, if 70 per cent is shrubs, and seabuckthorn accounts for 60 per cent of it, then with the deduction of 5 per cent of the area already covered, there will be 1,890-2,560 thousand hectares of land on which seabuckthorn should be planted. This equals 2.7-3.6 times the seabuckthorn forest area that currently exists. Extensive development of artificial seabuckthorn forests in this region will result in economic benefits as well as effective improvement of the soil and water loss over a relatively short period of time.

Seabuckthorn Afforestation by Air-seeding

Seabuckthorn has some positive biological features, e.g., the germination rate of seeds is high and the emergence of seedlings is fast, it has a strong root system, and it has the powerful capacity to form root turions. All these features make seabuckthorn suitable for air-seeding. Once it is sown and grown, rational cutting and improvement establishes the mass groves that will survive for many years.

Successful Examples of Seabuckthorn Air-seeding

Since the 1950s, seabuckthorn afforestation through air-seeding has been carried out in the mountain areas of northwestern China. Some successful experiences are discussed below.

1. In December 1959, on the Niangniang Mountain, Datong County, Qinghai Province, where the altitude is between 2,800-3,100m and the area falls into the cold alpine region and receives 576.4mm of precipitation, about 1,333 ha of slopy mountain land were afforested with seabuckthorn by air-seeding. According to investigations carried out in late July, 1960, 8,385 plants per hectare had survived and the area covered with seabuckthorn seedlings accounted for 45 per cent of the total air-seeded area.

2. In 1982 (July 20-22), the Lanzhou Civil Aviation Bureau and the Lanzhou Forestry Bureau jointly conducted experimental air-seeding in the Gaolan Mountain, Lanzhou, Gansu Province. This air-seeding covered 78.4 ha of wasteland with seabuckthorn seeds, totalling 7.5 kg per hectare. According to investigations made in October, 1982, there were 1475.7 seedlings per hectare on this mountain and the area covered with seedlings accounted for 75 per cent of the total air-seeded area.

3. From 1977 to 1979, the Northwestern Institute of Soil and Water Conservation, Academia Sinica, carried out an air-seeding experiment on 1,240 ha of mountain land in Wuqi County, Shanxi Province, a typical semi-arid, Loess Plateau Region. In 1983, a sample investigation made in the area showed that there were 21,905 to 40,960 seedlings per hectare remaining and most of the air-seeded area was covered with massive forests of seabuckthorn.

4. In 1982, air-seeding, using mixed seeds of Chinese pine (*Pinus tabulaeformis*), spruce, and seabuckthorn, was carried out in Xihe County, Gansu Province, and in 1987 another air-seeding operation, using mixed seeds of Chinese pine, Chinese arborvitae (*Platycladus orientalis*), and seabuckthorn, was carried out in Qingshui County, Gansu Province. The air-seeded areas of those two counties amounted to 1,714 ha. Investigation carried out in the autumn of the same year showed that the survival ratios were 30,015 and 18,000 seedlings per hectare respectively in those two counties (the survival ratio included 3 species of plants) and that the average height of the seedlings in the air-seeded area had reached 4.3cm.

To summarise the experiences above, it may be said that in lands that are characterised by large areas and sparse populations, serious soil and water losses, and annual precipitation of more than 400mm, such as the hill-ravine area of the Loess Plateau, China, seabuckthorn afforestation by air-seeding is an effective measure of accelerating and recovering vegetation, as well as of enhancing seabuckthorn forest and promoting the development of agriculture, forestry, and animal husbandry in these areas.

Many years of experience with seabuckthorn air-seeding have proved that it is a very promising method. The following are some of the advantages: generally, the seed quantity per hectare is only 0.4-0.5kg, but if an aeroplane (in the Chinese case, a small aeroplane, Yun-5, is used) flies 5-7 flights per day, it will cover 1,334 ha. Leaving aside the cost of seeds, the expense of air-seeding is 60-75 *yuan* (1.27-1.59 US$) per hectare which is one-third of the cost involved in artificial afforestation. Furthermore, compared to the artificial afforestation of seabuckthorn, air-seeding has some special advantages, such as speed, more effectiveness, a wider range, and low cost. It seems that the technology of air-seeding can be popularised in the vast mountain areas (Wang Zhengmin 1990).

In order to speed up vegetation recovery to control soil and water loss, an experiment in the air-seeding of seabuckthorn and other herbs and shrubs was carried out in Wugi County, a semi-arid region of the Loess Plateau, China, from 1977 to 1979. Air-seeding of seabuckthorn has been successful and also popular in large areas of north, northwestern China. It is believed that air-seeding is an effective way to accelerate the control over soil and water loss and to exploit seabuckthorn. The results of the experiments from 1987 to 1988 are summarised in the following passages.

The Natural Conditions of Seabuckthorn Air-seeded Areas. The experimental air-seeded areas are located in the northwestern part of Wugi County, at an elevation of 1,365-1,650 masl and belonging to the loess, hilly, gully regions where the Luohe River originates. The annual mean temperature is 7.5°C, the minimum temperature -27°C, and the maximum 35.5°C. The annual rainfall is about 380mm. The experimental areas, according to vegetation zonification, fall into the shrub-steppe region of temperate pastures. Forty years ago, there were some seabuckthorn shrubs as well as other species, but currently the natural shrubs are almost totally destroyed and the existing natural vegetation is composed of herbaceous communities of Bunge Needlegrass (*Stipa bungeana)*, Mongolian Thyme (*Thymus mongolicus*), Fringed Sage brush (*Artemisia frigida*), Stemless Cinguifoil (*Potentilla acaulis*), and Wormwood (*Artemisia gmelinii*). The lands were not treated before air-seeding and the seeds of seabuckthorn were sown on the natural vegetation, young plantations, and derelict lands. In the three-year experiment in air-seeding, two years were successful. Many tracts of air-seeded seabuckthorn forests can currently be seen in this area.

The Results of Air-seeded Seabuckthorn and the Main Constraints. In order to determine the most appropriate air-seeding time, artificial sowing experiments were carried out during different times in 1975 and 1976. The results indicated that from the last ten days of June till the 20th of July was the right sowing time. Thus, seabuckthorn air-seeding was carried out during the three years from 1977-1979. It was observed that the emergence of seabuckthorn seedlings by air-seeded area and the density of seedlings were quite different during different years. The survival rate of seedlings in the year sown was about 1 to 25 per cent, and 60 per cent of the young seedlings died during the following winter. However, after the third year, the percentage of the area and the plant numbers increased each year because the plants by then began to sprout seedlings from the roots.

Despite the low survival rate of air-seeded seabuckthorn, there was one plant per $10m^2$, on average, on the air-seeded land. After several years, the air-seeded land was covered with close stands of seabuckthorn. In other words, air-seeding of seabuckthorn can be successful.

The rainfall situation after air-seeding is a major constraint influencing the air-seeding results. Surveys showed that the seeds sown on the earth's surface germinate well when there are 6 to 8 continually cloudy and rainy days and more than 50 to 60mm of precipitation. If the seedlings form three pairs of microphylla in the 50 to 60 day growing period, their survival chances are better during winter. The seeds cannot germinate well unless there is enough rainfall after sowing. If the continuous rainfall is too late, or the frost comes in too early, the seeds germinate late and the seedlings cannot survive through the following winter. In addition, seabuckthorn seedlings are sensitive to high temperatures, the unlignified young seedlings are easily scorched and die in temperatures of 40° to 50°C. In most regions of the Loess Plateau, the rainy season is concentrated in July, August, and September and the amount of rainfall in these three months accounts for 60 per cent of the total annual rainfall. Thus, this provides a favourable condition for air-seeding. The experiments also showed that when the seeds were sown on loose earth, such as derelict land or young artificial woodlands, the young seedlings emerge faster and are stronger, but on dry and hard land, germination could not take place easily and the seedlings did not emerge well. In fact, most air-sown seabuckthorn forests were distributed on shady slopes and on loose land.

The Establishment and Nurturing Process of Air-sown Seabuckthorn Woodlands

According to observation, the air-sown seabuckthorn plants began to propagate through the root turion from the third or fourth year onwards. The seedling area and density then increased year after year. The more the soil moisture, or the lower the density, the more and earlier the sprouting. When the density of plants reached 2 plants/m^2 and the canopies clustered together, the topmost leaves and branches rose higher for want of light and excess absorption of soil moisture occurred, therefore some plants began to wither and die. This is the reason why, after about seven years, the density of the plants in the air-sown forests began to decrease.

Air-sown seabuckthorn forests can be transformed or nurtured for different uses according to their site types. Their special uses are discussed below.

A. For Soil and Water Conservation. On steep and broken slopes, a high density of air-sown seabuckthorn forests should be maintained in order to control soil and water loss. After 5 to 6 years, the crown density of seabuckthorn woodlands can increase up to 80 per cent from the previous 20 to 30 per cent, and, in seabuckthorn forests, litter can accumulate up to a

thickness of 2-6 cm and it can hold twice as much water as the weight of the litter. In addition, compared to natural mountain slopes, the nitrogen-fixing ability of the root tubercles of seabuckthorn can increase the nitrogen contents and the organic matter of the soil, in 10cm depth, by 1.7 and 2.1 times respectively. Thus, herbaceous plants in seabuckthorn forests grow luxuriously, and they enhance the conservation efficiency of the soil and water.

B. For Orchards. On gentle slopes, air-sown seabuckthorn forests can be transformed into orchards. Thinning out male plants, maintaining the male and female ratio at 1:8-1:10, and spacing the rows 3-4m apart and the plants 1m apart, seabuckthorn forests can be transformed into orchards. By using fertilisers and pruning the withered and diseased branches, the fruit yield of seabuckthorn orchards can be improved. Investigations carried out in 1987 showed that the fruit yield of a transformed forest reached 1,100kg/ha, whereas the untransformed forest only yielded 420kg/ha.

C. For Timber. Straight, sturdy seabuckthorn plants can be selected or nurtured into small pole-like stands by thinning and pruning. These micro-phanerophytes can be used to make farm tools and furniture.

D. For Firewood and Grazing. Air-sown seabuckthorn woodlands provide lots of firewood after thinning and strip-cutting. The leaves of seabuckthorn are rich in nutrients and they can be used as animal feed. After strip-cutting, rich herbages can be grown along the row or beneath the seabuckthorn plants. This kind of woodland can become good grazing land (Li Daiqiong et al. 1989).

The Role in Maintaining an Ecological Balance

Benefits for Mankind and Animals

Once seabuckthorn forest has been established on a large scale (e.g., in Jianping County there are 56,000 ha of seabuckthorn forest covering mountain slopes which used to be bare and arid), it can bring about enormous environmental changes and form special natural landscapes in the concerned area. Seabuckthorn forests not only improve the microclimate, control loss of water and soil, and provide fuelwood, but also give added dividends. According to investigations made in Lougu Gully, after the seabuckthorn forest coverage reached 57 per cent, wildlife returned to the forest. This benefits both the farmers as well as the wildlife. Attracted by a suitable habitat and seabuckthorn fruit that cling to the branches right through winter to the following spring, 8 animal species and 25 bird species have inhabited this forest and are recovering their numbers. Every year, from seabuckthorn forests, the local farmers collect about 30,000kg of wild edible fungi which is worth 8,000 US$ and they trap about 25,000 rabbits worth 38,000 US$. From these items, the farmers in Loufu Gully make an annual cash income from seabuckthorn forests of 16-30 US$ per household.

Ecological Balance

A survey on the interaction between seabuckthorn and some birds and beasts conducted by the Shanxi Institute of Biology and the Northwestern Plateau Institute of Biology, Academia Sinica, revealed a wide ecological significance. For example, in the Loess Plateau Region, among over 360 known living bird species, there are 51 species that are entirely dependant upon seabuckthorn as a food and 80 species that are relatively dependant upon seabuckthorn. As mentioned before, the ripe seabuckthorn fruit cling to the branches for several months. In winter, the importance of the fruit increases as it is almost the only food available for the birds perched there. Especially for the rare bird, *Crosoptilon manchuriam*, seabuckthorn fruit accounts for 48.1 per cent of its food and for *T. alaschanicus* it accounts for 58.4 per cent. Thus, it can be seen that seabuckthorn is of vital importance to birds. In the Loess Plateau Region, among about 60 known living animal species, 29 species have been found to inhabit seabuckthorn bushes and for 27 species seabuckthorn stems, leaves, flowers, roots, fruit, and seeds serve as food. Carnivorous animals, such as *Canis lupus, Felis pardus, Vulpes vulpes, Felis bengalensis,* etc often seize their prey and take shelter in seabuckthorn bushes. There are indications that the number of beasts increase as seabuckthorn bushes increase and become forests.

However, for seabuckthorn that are producing fruit it causes damage when the seabuckthorn is eaten by birds and animals, but despite this it is an effective way to transfer seeds through the digestive tubes of birds and beasts. Results of experiments have shown that the rate of germination of seeds from the stool of *Turdus ruficollis* is 65 per cent and that from the stool of *Lepus capensis* it is 35

per cent. Due to the ever- increasing scope of human activities, the natural habitats of birds and animals are decreasing, resulting in extinction and a substantial reduction of certain species. The protection and development of seabuckthorn resources are in many ways beneficial to the existence of birds and animals. Therefore, seabuckthorn forests provide long-term benefits in terms of maintaining ecological equilibrium (Ma Zhiben et al. 1989).

Seabuckthorn as Fuelwood Forest

Importance of Fuelwood

The question of domestic fuelwood supplies in the developing countries has gained prominence in past decades. In the HKH Region, by far the most important source of energy is plant biomass in one form or another and hardly anything else is of any significance to most farmers. According to the Forest and Soil Conservation and Agricultural ministries in Nepal, forests constitute 37 per cent, bushes, 5 per cent, and grassland 12 per cent of the total cover in the country. In the central hill region of Nepal, the biomass from forests, including shrublands, supplies approximately two-thirds of the total annual fuel supplies produced rurally. The rest (one-third or so) comes from private land in the form of agricultural crop residues, tree fodder residues, and some other forms (Mahat 1987).

As has been previously mentioned, in China 60 per cent of the 800 million farmers face a shortage of fuelwood for 3 to 5 months each year. In the rural areas of the arid and semi-arid regions, because of lack of fuelwood, a number of farmers have only two meals per day. Unfortunately, Chinese farmers in this area are less lucky than Nepalese farmers, because the latter can at least collect fuelwood from rich resources of forest, bush, and grassland. In some areas of the Loess Plateau, especially during spring, the farmers have to dig up even the roots of weeds for cooking fuel because the stock of crops has already been consumed. For example, in Wugouxian, Zhengyuan County, Gansu Province, every year the households have to spend 70-140 mandays to dig turf and roots for fuel, and these too are very sparse and scattered throughout the area. Furthermore, an average of 170 kg of dry dung/annum/person is consumed as fuel and this in turn leads to the degradation of the soil because of lack of dung for the fields.

Potential of Seabuckthorn as Fuelwood

Resolving the problem of energy shortage in the rural areas is a big challenge both for the Government as well as for the farmers. Seabuckthorn has proved to be a popular green energy plant because of its high quality biomass. Based on this knowledge, a programme for the purpose of establishing fuelwood forests of seabuckthorn has been carried out in Luofu Gully, Jianping County, Liaoning Province. During the seven year (1982-1988) period, more than 4,000 ha of seabuckthorn seedlings were planted in Luofu Gully and more than 20,000 ha of the same were extended over the whole county. Experiments and calculations carried out in a six-year old artificial seabuckthorn forest in Luofu Gully, revealed that each hectare can produce 18 tons of fuelwood. As the average calorific value of dry seabuckthorn wood is 4785.5 calories per kilogramme, which is more than that of most species of trees, one ton of seabuckthorn wood is equal to 0.68 of a ton of standard coal. It is estimated that, if the farmers grow seabuckthorn for fuelwood, every household may save four tons of standard coal per year. Based on the experiment, it is recommended that the proper planting density of seabuckthorn is 6,600-9,999 plants per hectare and the first harvest (cutting) time should be when the plant is six years' old, the time when it can produce the maximum biomass. The best cutting time is from December to March when the plant is in the dormant period. After the plant above the ground is cut, from about 94,000 to 95,000 root turion seedlings (new plants) per hectare will emerge in the next growing season. This means that seabuckthorn can provide a lot of fuelwood in a short period and can be used sustainably over the long term (Jiang Shumao et al. 1988).

V. Plantation and Management Techniques: Chinese Experience

Seabuckthorn, as discussed earlier, has vast potential to support high value commercial activities, meet the biomass needs of the people, and perform resource-conservation upgrading functions. However, the level and quality of the above gains can be substantially raised by the scientific propagation and management of seabuckthorn plantations.

This section discusses these issues by drawing on Chinese experiences. This may involve some unavoidable repetition of issues raised in the preceding section.

Although seabuckthorn has been used for centuries, no plantations existed for industrial purposes in China until the 1980s. From the end of the 19th century until the beginning of the 20th, seabuckthorn was introduced into most of the botanical gardens of Europe (e.g., Finland, Sweden, Norway, England, Germany, and Russia). Since that time, many horticulturists have introduced seabuckthorn into their gardens as an ornamental plant or as a fruit tree. Until the end of the Second World War, there was almost no modern plantation in any country. In the 1950s, Soviet scientists, led by M.A. Lisavenko, collected more than 20 varieties from natural forests. After analysing the chemical compositions of the fruit, five of the best were identified from this collection and were given a variety of names: Altai News, Katuni Gift, Golden Spike, Vitamin Seabuckthorn, and Oil Seabuckthorn. In the 1960s, these five varieties were cultivated in Altai, Menovo, and the Novosiberian States; perhaps they were the first batch of plantations in the world.

In the 1940s, seabuckthorn was planted for soil and water conservation and for firewood in some places in northern and northwestern China. In China, currently, most seabuckthorn products are made from wild fruit collected from natural forests that extend over more than 670 thousand hectares. However, the existing, natural seabuckthorn forests cannot satisfy the needs of the processing industries because of lack of management and low yield per unit area. Apparently, on one hand, artificial plantations with high yield and of good quality need to be established in order to provide stable raw materials for processing industries and, on the other hand, the existing natural seabuckthorn forests should be transformed into higher yielding forests so as to tap the production potential.

Transformation of Natural Seabuckthorn Forest

Natural seabuckthorn forests exist not only in China and the former USSR but also in many of the countries of Eurasia, especially in the Hindu Kush-Himalayan Region in the countries such as Afghanistan, Pakistan, India, Nepal, Bhutan, and Burma. Ecologically, these natural seabuckthorn forests are generally distributed along river banks. In some places they are concentrated on the wider river beaches and form mass forests. Therefore the use and transformation of these mass seabuckthorn forests into semi-cultivated forests is of universal significance. A series of experiments on the transformation of natural seabuckthorn forests have been conducted by the Beijing University of Forestry, Yuyu County, Shanxi Province, and the results have been successful and inspiring. The major points relating to their achievements are discussed below.

Measures for Transforming Natural Seabuckthorn Forest

Intermediate Strip Cutting. This is suitable for seabuckthorn forests that are neat and have plants from young to middle age. According to design, the reserve strip should be 2m wide and the intermediate space should have a width of 2 to 2.2m. In the reserve strip, other trees that are not required, male seabuckthorn trees, and the dead and diseased plants should be dug out completely. By strip cutting and pruning the trees should be spaced about 1m apart. In addition, each strip should contain a male-female mix in which there should be a male plant as a polliniser every 4 to 5m, so as to make up a male-female ratio of 8:1. In the reserve strip, if seedlings are missing, large seedlings should be planted in these empty spots. In order to avoid growing coppice shoots, the roots of the felled trees should be dug out and then the hollows should be levelled.

Intermediate Strip Cutting and After-Planting. This is suitable for agglomerate seabuckthorn forests since there are

areas of seabuckthorn growth within agglomerate forests. Intermediate strip cutting and chopping can be carried out on lands with seabuckthorn forests. To carry out operations after planting in these areas, the large seedlings should be planted out following the model of intermediate strip cutting as described above. The distance between the trees and the rows should still be 1m and the ratio of male-female 8:1. Usually, the size of the planting pit is about 40x40x40cm, the height of the big seedling 2m, with a root system of 30x30x30cm. After seedlings are planted, 25-50 per cent of the crown of the tree should be pruned.

Wide Intermediate Strip Cutting. This is suitable for tall and old seabuckthorn forests. Cutting above the root collar and improvement cutting are the two measures adopted. The reserve strip has a width of 4 to 8 m. In the reserve strip, most female plants are kept with a distance between the trees of 1m. Where there are no female plants some male plants should be reserved. In intermediate places, the seabuckthorn trees are cut above the root collar without digging out the stumps. After turions grow out of the collar, they should be cut, maintaining a distance of 1m.

Cutting Above the Root Collar. This is suitable for seabuckthorn forests that are accompanied by other trees and have a neat form. All the trees should be cut above the root collar. The stumps of non-seabuckthorn trees are dug out. Once the seabuckthorn stump shoots sprout out, and the shoots grow up to be trees that can be identified as male or female, in order to maintain the proper ratio of male and female plants, some of the plants should be weeded out and a number of male plants reserved as pollinisers. Generally, the sprouted seabuckthorn trees bear fruit during the fourth year. This measure is especially suitable for the regeneration of old seabuckthorn forests.

Improvement Cutting. This is suitable for seabuckthorn forests with neat form, of middle age, and accompanied by other trees. First, the other trees and the male seabuckthorn trees have to be cut down and the females spaced out 1-2m apart (depending on the size of canopy and density of seabuckthorn). Second, care should be taken that the female plants are well distributed, i.e., without missing any plants after intermediate cutting. Because the original seabuckthorn forests are not altered very much and there already exist trees of fruit-bearing age, these forests can produce high yields the year following their transformation. The disadvantages of this measure are that these forests are difficult to establish and to manage on a large scale because there are no roads going through the seabuckthorn forests and it is difficult to carry the felled branches out of the forest.

Effects of Transforming Seabuckthorn Forests

Over a period of four years, 13.3 ha of transformed forests have been established; among these most have been established by adopting intermediate strip cutting. Remarkable economic benefits have been obtained through these experimental plots. In 1987, investigations on 3.3 ha of transformed seabuckthorn forest, set up in 1986, were carried out and it was discovered that compared to the yield of 402 kg/ha of non-transformed similar forests, the yield of the transformed forest, at 3,375 kg/ha, was 8.4 times higher. In August 1989, investigations were carried out on all the experimental plots and the results are shown in Table 19. From Table 19 it can be seen that the yield of the transformed seabuckthorn forest reached 4,761.6 kg/ha four years after adopting intermediate strip cutting. The yield from non-transformed forest was 765.0 kg/ha. The former was 6.66 times that of the latter. Adoption of different measures brought forth different results in the yields of the transformed forests. This can perhaps be explained by the fact that the reserved number of seabuckthorn trees per unit area and the age of trees were different in each forest. It seems that the yield from the forest, transformed by adopting wide intermediate strip cutting, was the highest; it reached 14,808.8 kg/ha.

Analysis of the Economic Benefits

The following are some of the reasons that explain why the yields of transformed forests increased: the ecological conditions were improved, the canopy of seabuckthorn trees was widened, and the ratio of female and male was regulated to 8:1.

Transforming natural seabuckthorn forests into seabuckthorn orchards is the fundamental method for obtaining fruit for commercial purposes. Experiments have proved that it does not require much investment, and the returns can be obtained rather quickly. According to calculations, the total investment for 3.3 hectares of transformed seabuckthorn forest was 2,528 *yuan* (535.6 US$) or 766 *yuan* (160.2 US$) per hectare.

In the first year, intercropping can be carried out on the space of land in between the strips. Because the soil of the

land where seabuckthorn was grown before is fertile, and there is enough sunshine, the intercrops grow well and give a good harvest. For example, if potatoes are planted on those pieces of land, the output value of the potatoes will compensate for the cost involved in transforming the seabuckthorn forest.

The intercrops can still be grown in the second and third years, however the yields would decrease gradually. From the fourth year onwards the yield of seabuckthorn fruit would increase substantially. Concrete examples of increase in yields by 3.32 times, and in output value by 735.55 to 7177.90 *yuan*/ha (155.8-1520.7 US$/ha), make it apparent that transforming the natural seabuckthorn forests is profitable for the farmers who live in the mountain areas where massive natural seabuckthorn forests exist.

The intercropping not only increases economic benefits but also prevents the growth of weeds and sprouting of root turion seedlings which normally occur in seabuckthorn forests.

Table 19: Comparison of Fruit Yields of Transformed Seabuckthorn Forests by Different Measures (August 1989)

Measures of Transformation	Age of Tree (year)	Area of Exper. (m^2)	Yield of Fruit (g/tree)	Yield of Fruit (kg/ha)	Increase (times)
Intermediate strip cutting	8-10	396.0	396.0	4761.6	6.66
Intermediate strip cutting and after planting	8-10	312.8	546.8	2186.1	3.06
Wide intermediate strip cutting and cutting above root collar	10-13	122.0	1050.6	14808.8	32.09
Improvement cutting	10-13	264.0	998.4	4538.3	10.02
Cutting above root collar	10-13	147.8	422.8	2285.1	5.04
Intermediate strip cutting (1988)	10-13	284.0	651.6	2019.0	4.46
Contrast	8-10	112.0	114.9	715.0	-

Source: Kou Jilie et al. 1990

Artificial Plantation

Demand for seabuckthorn fruit, and especially for seabuckthorn oil, is increasing year by year. Establishing new seabuckthorn plantations to meet the demand of industries is an urgent task. From the 1960s, the former USSR began to set up artificial plantations, and, by now, more than 6,000 ha of artificial seabuckthorn orchards have been established; among these 3,000 ha are distributed in the Altai Border Region. Some European countries, as well as China, are only just beginning to set up artificial plantations. Therefore, experiences gathered from the former USSR are very valuable for these other countries. Discussed below are some points in reference to establishment of new artificial plantations.

Plantation Establishment

Plantation Site Selection. Based on the distribution of natural seabuckthorn forests, it can be stated that river banks are most suitable for setting up plantations on a large scale. If plantations are to be established in arid areas a good water supply has to be assured. On river banks, seabuckthorn can

tolerate inundation because flood water contains oxygen, however shallow kettle holes, where rain and snow are easily gathered, are not suitable for establishing seabuckthorn plantations. In addition, places where the groundwater level is less than 0.5m are also not suitable for seabuckthorn. Sand soil and loamy, rather than clayey, soil are preferable for seabuckthorn plantation because, in these soils, the plants survive longer but in the latter they do not. In the former USSR, black earth and sod-podzol soil were found to be the best for growing seabuckthorn.

Land Preparation. Before planting seabuckthorn, some necessary measures have to be adopted in order to increase the organic matter content. Generally, sowing perennial herbs and green manure crops and applying large amounts of organic fertiliser are common measures that ought to be taken.

The land should be kept in dead fallow for 1 to 2 years before planting. During this period, the land should be ploughed deeply and harrowed. Perennial weeds with deep root systems should be destroyed by using herbicides such as sodium trichloroacetate, dalapon, and ammonium 2,4-D.

It is recommended that in order to ensure the fertility of the ploughed land, 100 to 150 tons per hectare of compost or barnyard manure should be spread on the land. If the content of humus in the soil is more than 4 per cent, the amount of organic fertiliser spread on it can be reduced by 50 per cent. In the absence of organic fertiliser, green manure can be used instead. Sowing green manure crops continuously for two years can provide 400 to 500 tons of green organic matter to the soil and this is equivalent to 800-1,000 tons of semi-decomposed dung.

If the soil is acidic, lime should be added into the soil in order to raise the efficiency of mineral fertiliser. The seabuckthorn plant is very sensitive to the increase of phosphorus in the soil, and, further, it does not activate the plant in anyway. Therefore, it is better to apply 600 to 800 kg per hectare of calcium superphosphate to the soil before ploughing it deeply.

Planting Time. Seabuckthorn is one of those plants for which autumn is not a suitable planting period because of the constraining feature of the roots. It has been proven that the survival rate of seedlings planted in autumn is much lower than of those planted in spring. Most seedlings planted in autumn die over the following winter. Even if seedlings are dug out in autumn, temporarily planted over winter, and dug out again for planting in the field next spring, the survival rate is still low. A high survival rate is ensured only when the seedlings are dug out and immediately planted in the field during early spring before the seedlings start sprouting. If the time taken for temporary planting in spring or the time for transporting seedlings from the nursery to the field is too long, the survival rate decreases. The roots of seabuckthorn are sensitive to wind and sunshine and drying should be avoided. It is good to place the roots in muddy water before planting.

Disposition of Pollinisers. Seabuckthorn is a typical dioecious plant. The number and disposition of pollinisers directly influence the yield of the plantation. The Siberian Institute of Horticulture, of the former USSR, established 311.5 ha of experimental plantation between 1962 to 1963 in order to assess the relationship between polliniser and yield. The disposition of pollinisers is shown in Figure 1 below.

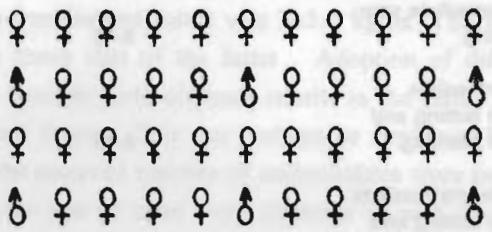


Figure 1: Disposition of Pollinisers

According to this disposition, between every two lines of female plants there is a mixed line . In this mixed line, after every four female plants there is a male plant. This means the pollinisers account for 6-7 per cent of the total plants. Generally, the distance within which the female plant can be pollinated is about 100m. Investigations have shown that as the distance from the female plant to the male plant (polliniser) increases (64m or so), the yield of the female plant decreases. Therefore, for balanced pollinisation, the disposition of pollinisers illustrated above is suitable.

For more effective pollinisation, male seedlings that have different blooming periods, a higher pollen preservation rate, and tolerance of bad weather should be selected as pollinisers. If both the male and female plants are vegetative seedlings, the male plants will blossom at the same time. If the weather is not suitable, concomitantly ripe pollen cannot be spread by the wind, and hence the process of pollinisation cannot be carried out.

Management of Plantations

Irrigation. Seabuckthorn is sensitive to the moisture in the soil. For satisfactory growth and production, supplementary irrigation is needed to ensure profitable production. Experiments on irrigation, conducted by Berry Station in New Siberia, the former USSR, showed that in meadows of chernozem soil and middle clay loam, in conditions where the moisture content in the irrigated plot was more than 71 per cent compared to the moisture content in the non-irrigated plot of 51-65 per cent, irrigation enabled an increase in the crown diameter of seabuckthorn by 56 per cent and an increase in fruit yield by 47 per cent.

The minimum moisture contents permissible for specific soils are as follows: middle clay loam - 70 per cent; heavy clay - 80 per cent; slightly sandy soil - 60 per cent; and sand loam - 65-70 per cent. When the moisture content is lower than the levels mentioned above, especially during the blossoming and fruit- growing periods, irrigation is required. For example, the area of non-chernozem soil needs to be irrigated three times during the growing period (each time 400-500m^3/ha). In areas of East Siberia and Lake Baykal in the former USSR, where rain and snowfall are insignificant, irrigation is very important before the seabuckthorn faces winter, because sufficient water not only increases the temperature of the layer where the roots are distributed but also provides the moisture that the plant requires in the following spring. The average amount of irrigation required in these areas before winter is 500-600m^3/ha and it should be soaked to a depth of about 70-80 cm.

Fertilisation. Like all crops, seabuckthorn needs proper nutrition, but its optimum requirement is unknown at present. During spring, the seabuckthorn which has borne fruit begins to grow quickly by drawing upon the supply from store nutrients accumulated the year before. During the first phase of the growing period, because seabuckthorn needs a good supply of nitrogen, the nutrients are consumed to form roots and branches and to blossom. During the latter phase of the growing period, the branches stop growing and the nutrients are consumed by the formation of the fruit and flower buds. The nutrients then flow gradually from the leaves to the trunk, branches, and roots. During this period, the seabuckthorn plants need phosphate and potash fertilisers (Bukshtenov et al. 1985).

It is recommended that 45-50 tons of organic manure per hectare be applied to the seabuckthorn plantations every 3-4 years. The practice of fertilisation has proved that, under guaranteed water supply conditions, the effect of fertilisation increases substantially.

Form Pruning. By the end of the first four years, seabuckthorn grows up to 2-2.5m and forms its crown based on the growth of its central branch. The aim of form pruning is to make the scaffold branches take proper positions and to keep the crown compact and low in order to make it convenient for harvesting. For this purpose, the crown should be pruned regularly. Usually, the branches that overlap and those that are not in correct positions should be pruned off, and the slim and long branches should be cut short. From the fifth year, the central leading branch stops growing, and the plant no longer increases in height. The branches then grow out from the lateral buds and the pseudo-verticillate body. Meanwhile, the seabuckthorn enters into the stage of mass bearing. If the crown is dense, some branches should be pruned off so as to let sunshine penetrate the crown. During the following spring, all diseased, withered, and very low branches must be pruned. Generally, seabuckthorn begins to bear fruit in large quantities in the fourth or the fifth year. The peripheral branches of the crown grow or bear alternately. In order to prevent seabuckthorn from premature senescence, pruning for rejuvenation should be carried out on three-year old branches.

Propagation

Artificial plantations are established with cultivated seedlings, cuttings, grafted seedlings, and other propagated materials such as the seedlings from root turion or the plantlets produced through tissue culture. But the most important propagation methods are to cultivate seedlings from seeds and to use cuttings from hardwood or softwood trees.

Cultivating Seedlings from Seeds

Cultivating seedlings from seeds is a simple technology and has some definite advantages; it produces a greater number of seedlings, involves lower costs than other propagation methods, and seedlings thus produced survive better and grow faster compared to cuttings. This technology involves the following procedures.

Pre-treatment of the Seeds. Chinese seabuckthorn (*H. rhamnoides L.*, subsp. *sinensis*) seed is medium in size and

one kilo of air-dried seeds contains 130-140 thousand seeds. If the germination rate reaches 80-95 per cent, one kilo of seeds can produce 104-133 thousand seedlings. Before sowing, the seeds should be put into water at a temperature of from 60°C-70°C and stirred constantly until the temperature drops to from 10°C-20°C. Then the seeds should be soaked for two days. When the seeds have expanded sufficiently they are taken out and dried for sowing.

Seedbed Preparation. Seedbeds should be established in a place close to the expected plantation plot. This place should have convenient transportation and irrigation facilities. Before the seedbed is prepared, sufficient barnyard manure should be applied to the land, then the land should be ploughed under to great depth (about 20-25 cm) and meticulously broken up. Generally, the seedbed is 10 metres long and 1 metre wide. This size is convenient for operation and irrigation.

Sowing. As the temperature of the soil (5-10 cm depth) rises to 15°-20°C in spring, it is suitable for sowing. Ditch and drill seeding is commonly practised in northern China. The drill furrow is 4 cm in width and 2.5 cm in depth. The drill spacing is 20-25 cm across the seedbed. The seeds are sown in the drills evenly and covered with 1-2 cm of soil.

According to experience, seabuckthorn seedlings are weak in springing up from the soil, so seeds should not be sown deeply. After 12-18 days, most seedlings sprout. Then the key period follows, if the ground surface becomes dry and hard, the seedlings cannot sprout properly and will curl and suffocate under the surface of the ground. After the seedlings sprout, strong sunshine will hurt the young tender seedlings and sometimes they can die from branding. At this time, timely cultivation of the soil and breaking up the hard ground surface to avoid the temperature of the soil rising is necessary to decrease the likelihood of dead seedlings. In addition, seedlings should be covered with a mulch of straw to conserve moisture, or covered with a shade to protect the young seedlings.

After Care. When a seedling sprouts 3-5 pieces of microphylla, the seedling is not likely to die. From this period, weeding should be carried out frequently, otherwise the weeds will inhibit the growth of the seedlings. Insects living underground can also damage the young seedlings. Insecticides such as gammexame and dylox can be used to control these pests. When the growth is at 3-4 cm, excessively dense seedlings should be thinned down and weeds pulled out. During the rainy season (July and August), the seedlings should be 5-7 cm in height and more attention should be paid to draining the seedbed. If the accumulated water floods over the top of the seedlings, they will die when the water recedes and the sunshine comes out again. In order to promote speedy growth, supplementary chemical fertiliser is applied to the seedbed before or after rain. This measure may be carried out in combination with cultivating and weeding. To produce a seedling which is suitable for transplanting will take 6-18 months in a nursery (Li Ruzhi 1990).

Hardwood Cutting

Seabuckthorn is a dioecious, wind-pollinated plant. The seedlings propagated by seeds cannot maintain the fine biological characteristics and economic properties that are genetically identical to the selected mother plants. Among the seedlings there are usually more males than females, and it is difficult to distinguish males from females before flowering and fruiting. Cutting propagation can produce scion- rooted seedlings with the same genetic properties as those of their mother plants in a short time, and these can bear fruit 1-2 years earlier than the seedlings. This is an important technology for propagating improved varieties, for introducing and acclimatising new species of seabuckthorn, and for building artificial plantations.

Although hardwood cutting propagation technology has been widely used by agriculturists and horticulturists as well as by foresters, for example, in poplar cultivation, a large amount of research on seabuckthorn has shown that this plant easily takes root through cuttings, but the rate of rooting is very uncertain, so hardwood cuttings have not been widely used in nurseries. Because of the susceptibility of rooting to the environmental conditions in different regions, with different facilities, and different management levels, detailed study is necessary in order to increase the reliability of cuttings. From 1986 to 1988, a systematic and thorough research on the technique for using hardwood cuttings of seabuckthorn was conducted by Beijing Forestry University at Dabaoxiang Nursery, in Zhuolu County of Hebei Province. A series of techniques is summed up below.

1. The adventitious roots of hardwood cuttings of seabuckthorn usually strike above the leaf scars in a scattered manner. Each cutting has 3-5 roots which grow from the epidermis of the stem. Microscopic observation shows that the root initials originate from vascular rays and cambium. Although the cuttings take

root easily, the rooting is unstable and sensitive to changes in environmental conditions.

2. Dabaoxiang Nursery is located in a cold region (the annual average temperature is 4.6°C) at an altitude of 1,300 masl. By adapting large, plastic film canopies and small, plastic film canopies, the hardwood cuttings can be planted earlier, 30-40 days before plantation in the open field. Covering with straw screens at night can increase temperature, retain moisture, and protect the cuttings from frost. The cuttings begin to sprout roots eight days after being planted, when the accumulated temperature (equal to or above 10°C in 5cm depth of land) reaches 121.6°C. The cuttings take root in large numbers by the fifteenth till the twentieth day when the accumulated temperature reaches 315-317°C. After 30 days, a complete, semi-woody root system with lateral roots and nodules is formed. At this time, seedlings of the hardwood cuttings can be transported to nurseries for further cultivation.

The second batch of cuttings can then be raised (these cuttings are selected and stored in wet sand at a low temperature). Both the first and the second batches of the seedlings of hardwood cuttings reach the required standard during late fall.

3. Adequate aeration and water permeability in the soil are required when hardwood cuttings form adventitious roots. A man-made medium can ensure the needed temperature, moisture, and adequate aeration for rooting. Comprehensively, considering the rooting rate and survival rate, the better ratio for the medium should be - sand: humic soil: the soil under seabuckthorn vegetation - 5:3:1. In addition, all the cuttings of different ages have the capacity to form adventitious roots. Among them, the three year old cuttings have the highest percentage of root formation (see Table 20). Full use should be made of these characteristics in asexual propagation of seabuckthorn.

Table 20: Investigation of Rooting Rate 30 Days after Planting

Replication	1				2				3				4			
Media / Rooting rates (%) / Shoots' ages	I	II	III	IV	I	II	III	IV	I	II	III	IV	I	II	III	IV
A	33.3	44.4	88.9	77.8	33.3	55.6	44.4	33.3	55.6	33.3	66.7	66.7	22.2	44.4	44.4	33.3
B	88.9	55.6	77.8	33.3	66.7	55.6	88.9	44.4	66.7	88.9	66.7	44.4	77.8	55.6	88.9	44.4
C	100	22.2	77.8	88.9	100	44.4	55.6	77.8	88.9	33.3	88.9	88.9	100	11.1	77.8	77.8
D	77.8	22.2	33.3	60.0	88.9	77.8	55.6	100	77.8	33.3	77.8	75.0	55.6	66.7	66.7	88.9

Source: Huo Shuhua et al. 1989

Notes: ratios of media are: I. pure sand; II. sand: humic soil = 1:1; III. sand: humic soil: under seabuckthorn vegetation = 5:3:1; IV. sand: soil under seabuckthorn vegetation = 1:1, ages of shoot are: A. one-year-old; B. two-year-old C. three-year-old; D. four-year-old.

4. Three years of experiments have shown that the best time to take cuttings from mother trees is from October to January. The cuttings should be stored in wet sand at low temperature in a moist dark environment. Another good time to take cuttings from mother trees is middle or late March, and these cuttings should be immediately planted under a canopy. Standard cuttings should be taken from the base of a 2-3 year old shoot, 10-25 cm in length, and 0.8-1.5 cm in diameter.

5. Before planting, the bases of the cuttings are soaked in running water for a day and a night, or immersed into a container filled with water for one or two days (the water should be changed once or twice every day). When the bases of the cuttings are given a quick dip in 300-500 ppm NAA (naphthylacetic acid), the rooting rate is raised. If the cuttings are immersed in 50 ppm NAA solution for 24 hours, the same effects can also be achieved (Huo Shuhua et al. 1989).

Softwood Cutting

Usually, softwood cutting is an effective propagation method needing artificial mist sprays and a plastic film house with other equipment. The basic technique is summarised below.

Selection and Collection of Cuttings. The cuttings from small young shoots have no capacity to form roots, and the cuttings from highly lignified branches have a poor capacity to form roots. Seedlings from such cuttings have difficulties in winter. Both these cuttings are unsuitable for softwood cutting. Experiments have shown that shoots with medium growing power, in the same layer of the crown, of the same age, and exposed to sunshine, are most suitable for cutting. It is better to collect cuttings in the early morning when the leaves are covered with dew.

When the cuttings (15-20cm length) are cut off from the mother trees, they should be immediately put into plastic film bags to prevent them from wind-drying and withering. These cuttings will remain fresh for three days in this condition. The cuttings can also be maintained in water for one week without losing their rooting capacity.

Treatment of Cuttings. Each cutting must be cut into two sections of 7-10 cm lengths. One- third of the leaves on the cuttings should be eliminated from the base of these cuttings. Then the cuttings should be placed in water to stay fresh. Before auximone treatment these cuttings are taken out of the water and bundles of 50 cuttings, bound together with a rubber band, are put into a box filled with solution of IBA (indolebutyric acid) at a depth of 3-4 mm. The concentration of IBA solution is 50 ppm in the box. All cuttings soaked in the IBA solution should be covered with a plastic film to keep the moisture in and the solution in the box should be maintained at a temperature of 20-25°C for 16 hours. The cuttings treated with an auximone like IBA can strike massive adventitious roots. Before planting, these cuttings should to be taken out from the IBA solution and washed in order to remove the auximone.

Cultivating Softwood Cuttings. This needs to be carried out in the plastic film house equipped with an artificial mist sprayer and drainage facilities. The seedbed needs to be made flat and the medium of the seedbed should be of sand and humic soil mixed in a ratio of 3:1. Before cultivation, the seedbed needs to be watered to keep the medium wet enough. Before inserting the cuttings, use a marker to rule small shallow furrows in the seedbed (distance between the furrows should be 7 cm and the distance between the cuttings should be 3 cm). In this way, the cuttings are inserted into the medium at depths of 1.5-2.0 cm. If the placing of the cuttings is too close, they will be damaged by mould. After the cuttings are inserted into the medium, water the seedbed again to make the medium around the cuttings settle down.

Aftercare of Cuttings. The aim of aftercare is to raise the rate of rooting. The rooting of cuttings depends upon the temperature and moisture in the soil and air. When planting begins, the temperature of the soil should be higher than that of the air by 1-3°C. Generally, when the daily average temperature of open land is up to 18.5°C, the average temperature of the soil is up to 19.0°C, and the relative humidity of the air is 40-50 per cent. In the plastic film house the average temperature of day and night should be 19°C, the average temperature of the soil should be 24°C, and the relative humidity of the air should be 88-100 per cent. In order to maintain the humidity mentioned above, it is necessary to spray-mist in time. When the humidity of the polythene film house is sufficient, there is an apparent indicator - water membranes on the leaf surface of the cuttings. If the water membranes disappear, it shows that it is necessary to spray mist until the leaf surface retains water membranes again. When the cuttings have already taken root, the humidity should be gradually decreased and the area should be well ventilated. When autumn is coming, the rooted cuttings need to be gradually tempered. In the beginning, the plastic film is taken off for a short time every day, and this is increased day by day. After 2-3 weeks, the plastic film can be taken off completely. When winter comes, it is necessary to cover the place where the roots have taken with a layer (5-6 mm) of fallen leaves in order to prevent them from cold damage (Elmakov 1985).

Softwood cutting has also been studied by the Beijing Forestry University. There are two types of seedling cultivation equipment adopted by this university. One is a greenhouse which is equipped with an automatic intermittent mist sprayer controlled by an electronic leaf. Another is a small plastic film canopy equipped with an artificial mist sprayer and shaded by foliage. The favourite cutting time is from the middle of June to the beginning of August (in Hebei Province, China). When semi-lignified cuttings are used for softwood cutting, the rate of rooting can be 98 per cent . Both in the greenhouse and under the small canopy, the cuttings will put out massive adventitious roots and grow up to heights of 37-51 cm with average diameters of 0.67-0.92 cm above ground after two years of cultivation (Zhang Zhixiang et al. 1989).

VI. Conclusion

Prospects of Seabuckthorn

The brief review of seabuckthorn presented in this paper establishes a case for the promotion of seabuckthorn as a multipurpose option for fragile and marginal mountain areas. To recapitulate, one may again refer to its important features such as being a source of low-cost vitamins, a rich source of cash income and off-farm employment, and an effective means of slope stabilisation and soil moisture conservation.

Seabuckthorn, as a multipurpose plant, has been used in different fields, but its potentials are far from fully exploited. With further study, more and more uses could be developed in the near future.

As a Source of Low-priced Vitamins

Being a source of abundant amounts and varieties of vitamins is one of the remarkable characteristics of seabuckthorn (see Table 1). Because seabuckthorn (all species) bushes are always distributed throughout the cold, dry, and poor mountain areas which, in most cases, are not suitable for common fruit trees and vegetables, it can provide plentiful, low-priced vitamins for the people living in remote areas. For example, in Western Sichuan, China, the Tibetan herdsmen who live at high altitudes often collect fresh seabuckthorn (*H. thibetana*) berries to eat.

The most important thing is that seabuckthorn fruit is a plentiful source of Vitamin A. According to Pokhrel (1989), the latest medical research has proven that Vitamin A deficiency is not only the major cause of impairment of vision but also causes slow growth and increased vulnerability to metabolic disturbances. Referring to health problems caused by dietary deficiencies, the lack of vitamin A can be singled out as an acute problem in most of the developing countries. The latest available statistics reveal that the annual mortality rate of 150,000 pre-school children is a result of vitamin A deficiency alone. It is estimated that there are about 5 million children worldwide affected by vitamin deficiency. Of this number, 250,000 children are rendered blind each year in Asia alone. In Nepal, it is estimated that 15,000-20,000 child deaths can be prevented each year by increasing the intake of Vitamin A.

Seabuckthorn fruit oil is very rich in carotene (one carotene unit can be decomposed into two Vitamin A units) (see Table 2). According to Zhang Fushuan et al. (1987), some pulp oil (*H. rhamnoides L.*, subsp. *turkestanica*) from Xinjiang, China, contains carotene of up to 9265.5 mg/100g. There is a strong potential for the use of seabuckthorn oil in land-locked developing countries such as Nepal instead of cod-liver oil for treating Vitamin A deficiency.

As a Source for Generating Cash Income

Traditionally, farmers who live in the high mountains or remote areas have very narrow options for growing cash crops for additional income, since the weather and soil conditions are not suitable, or transportation constraints hinder the development of commercial production. That is one of the reasons why people living in remote areas are poorer than people living in the plains. Since the economic value of seabuckthorn has been revealed, people living in remote areas have found that the indigenous wild plant could bring them considerable income. For example, since 1985, in the middle reaches of the Yellow River, farmers have been earning about 1.06 million U.S. dollars from seabuckthorn fruit every year.

In the Hindu Kush-Himalayan Region, there is a tremendous amount of wasteland, especially on high altitude river terraces and dry river beds where soils are often gravelly, sandy, and lack organic matter, and where the weather is often cold, dry, and windy. Usually these lands are not suitable for ordinary farming or crop planting, but they are suitable for establishing seabuckthorn plantations. In fact, after the establishment of seabuckthorn plantations, local farmers may quickly reap benefits. For example, in Jianping County, Liaoning Province, since 1986, the farmers have been earning 400,000 US$ every year from seabuckthorn collected from newly established forest. This income does

not include the other benefits accruing from the by-products of the seabuckthorn forest.

As an Option for Stabilising Mountain Slopes

In the Hindu-Kush-Himalayan Region many roads need to be cleared every year, and stabilisation of mountain slopes to maintain roads year round is a priority. In order to meet this aim, selecting appropriate plant species to cover the mountain slopes is an important biological engineering measure. There are many species with wide ecological amplitudes which can be successfully planted over a wide range of climatic conditions and which can grow on the mountain slopes as well, but such species may not be accepted or adopted by engineers and farmers because they are of insufficient economic value.

Plant species that are capable of fixing nitrogen, are good soil binders, provide good surface cover, and can be significant as fodder, food, fuelwood, and medicinal plants are particularly favoured by planners and farmers. Seabuckthorn, perhaps, is just the kind of plant needed. When people understand and recognise the value of seabuckthorn, its appearance in roadside plantations in the HKH Region will be probable.

Seabuckthorn has its own limitations. For example, most species of *Hippophae* originate from temperate zones and may not adapt to a tropical or subtropical climate. Many species have too many thorns on the stems, so it is very difficult to pick the fruit and harvest it by machine. On the other hand, too many thorns provide an obstacle to sheep and cattle grazing.

However, the big challenge is the spreading and harnessing of this plant in different areas. In this respect, we may highlight some of the circumstances positively associated with the prospects of seabuckthorn, particularly in the HKH Region.

Experiences with Seabuckthorn in Three Countries

Until now, natural seabuckthorn bushes have only been found in Europe and Asia. According to the available literature, seabuckthorn (including all species and sub-species of *Hippophae L.*) is scattered throughout Norway, Sweden, Finland, the former USSR, Denmark, Poland, Germany, the Netherlands, Belgium, France, England, Ireland, Spain, Switzerland, Austria, Italy, Yugoslavia, Hungary, Romania, and Turkey in Europe, and Iraq, Iran, Afghanistan, Pakistan, India, Nepal, Bhutan, Mongolia, and China in Asia. About 30 countries in the world have been found to have natural seabuckthorn forests (see map on page 7).

From the map, it can be seen that seabuckthorn is distributed from several masl in Scandinavia to 5,000 masl in Tibet and it is found from the wet seashores to the arid plateaux. It suggests that seabuckthorn can adapt to widely varying ecological environments. However, the largest area of natural seabuckthorn forest is concentrated in China. The other two big producers of seabuckthorn are the former USSR and Mongolia (See Table 21).

The status of seabuckthorn exploitation in the former USSR has been discussed in Chapter 3. From Table 21 it can be seen that, in 1982, the former USSR had 47,205 ha of seabuckthorn forest and could harvest about 4,200 tons of fruit. Despite the fact that the former USSR is the second largest producer of seabuckthorn products, because of its huge domestic demand, neither the area nor the yield of seabuckthorn will meet the increasing requirements for a long time.

In China, seabuckthorn has provided a breakthrough in harnessing water and soil losses in north and northwest China, and it has generated remarkable benefits both for farmers and entrepreneurs, leading to its acceptance both by the public and the Government. The priority given to investment by the Government emphasises the resource bases of seabuckthorn. Now the total area of seabuckthorn has increased from 667,000 ha (1985) to about 1,000,000 ha (1990). The total value of seabuckthorn products has reached more than 20 million US $ (1990).

According to the Plan of the Chinese National Seabuckthorn Office, from 1991-1995 more than 333,000 ha of seabuckthorn forest will be established in China, most of which will be concentrated in Shaanxi, Xhaanxi, Gansu, Lianing, Inner Mongolia, Qinghai, and Ningxia provinces.

Mongolia is the third largest producer of seabuckthorn in the world. It has 29,000 ha (natural and cultivated), mainly located in the Ubsunuur (accounting for 45%), Central, Oriental, Selenge, Dzarhan, Koldo, and Hovsgol provinces.

The fruit of seabuckthorn is a favourite berry of the Mongolian people and seabuckthorn oil is used in Mongolia as a medicine and health food.

Table 21: Seabuckthorn Resources and Their Distribution in USSR, Mongolia, and China

Distribution Region	Seabuckthorn Area (hectare)			Possible Harvested Yield (ton)
	Natural	Cultivated	Total	
USSR (1982)				
Russian S.F.S.R.	13,970.0	3,480.0	17,450.0	2,230.0
Georgian S.S.R.	400.0	30.0	430.0	50.0
Armenian S.S.R.	-	1,000.0	1,000.0	200.0
Azerbaijan S.S.R.	7,300.0	10.0	7,310.0	400.0
Uzbekistan S.S.R.	1,230.0	40.0	1,270.0	200.0
Tajikistan S.S.R.	2,860.0	600.0	3,460.0	300.0
Kirghizian S.S.R.	4,990.0	20.0	5,010.0	300.0
Kazakhstan S.S.R.	10,270.0	-	1,0270.0	500.0
The Other S.S.R.	30.0	975.0	1,005.0	20.0
Total	41,050.0	6,155.0	47,205.0	4,200.0
Mongolia (1990)				
Ubsunuur Province	12,680.0	370.0	13,050.0	1,174.0
The Other Provinces	15950.0	-	15,950.0	986.0
Total	28,630.0	370.0	29,000.0	2,160.0
China (1990)				
Shanxi Province	313,333.3	20,000.0	333,333.3	139,000.0
Shaanxi Province	125,466.7	33,200.0	158,666.7	66,000.0
Gansu Province	143,333.3	26,666.7	170,000.0	11,000.0
Liaoning Province	-	124,666.7	124,666.7	15,000.0
Qinghai Province	53,200.0	27,466.7	80,666.7	15,4000.0
Inner Mongolia A.R	14,533.0	61,660.0	76,133.3	3,500.0
Xinjiang A.R	33,333.3	-	33,333.3	13,300.0
Hebei Province	25,866.7	2,133.3	28,000.0	5,000.0
Sichuan Province	26,666.7	-	26.666.7	11,600.0
Other Provinces	4,933.3	1,466.7	6,4000.0	1,500.0
Total	740,666.6	297,200.1	1,037,866.7	281,300.0

Source: 1. USSR, N.T. Koykov, 1985
2. Mongolia, Huang Quan et al. 1990
3. China, Lu Rongsen, 1991 (Data are collected from various Chinese literature)

The fresh fruit and products do not always meet market demands, and sometimes products are sold without entering the retail market. The Mongolian Government has paid a lot of attention to developing seabuckthorn forests because of the plant's multiple uses for foods and medicines, for controlling soil and water losses, and for afforestation in and around the cities. By 1995, the existing 370 ha of cultivated seabuckthorn plantation will be extended to 1,000 ha and by 2,000 A.D. more than 3,000 ha of seabuckthorn plantation will have been established.

For other countries, comparable statistical details are not available. However, a few small-scale explorations sponsored by ICIMOD (which are still in progress) indicate

substantial areas of seabuckthorn in Nepal, India, and Pakistan. Thus, seabuckthorn is not a new thing for the HKH Region. However, unlike China, other countries of the HKH Region have hardly done anything to promote seabuckthorn. The real value of this review, illustrating mainly the Chinese experience with seabuckthorn, is to generate awareness and induce action in other parts of the HKH Region.

Demonstration of Potential

The important lessons from Chinese experiences relate to (i) a large-scale plantation of seabuckthorn (including by air-seeding) as a part of resource conservation strategy for fragile slopes; (ii) conversion of wild plantations into a managed system to enhance productivity of seabuckthorn (including by changing the ratio of male-female plants and by introducing methods of easy harvesting and processing of seabuckthorn fruits); and (iii) development of processing technologies for different seabuckthorn products and establishing processing units and marketing channels for them. All this has helped to generate high cash incomes and comparative advantages for seabuckthorn producing areas.

Strategies

To facilitate the spread and harnessing of seabuckthorn based on Chinese experience, the strategy needs appropriate steps. They include the steps listed below:

(i) generating awareness;
(ii) field exposure and training; and
(iii) establishment of demonstration units involving experts from China and other countries.

To, at least, partially meet the above requirements, ICIMOD has initiated a few activities. They include:

(i) preparation of a video film with Chinese cooperation to generate awareness about seabuckthorn;
(ii) the visit of a mission from the Chinese Office of Seabuckthorn to ICIMOD; their visit to seabuckthorn growing areas in Nepal; exhibition of over a dozen seabuckthorn products; a business seminar involving Chinese experts and experts from other countries, (mainly from Nepal);
(iii) plans for training selected people from different HKH countries through field visits to China in 1992; and
(iv) other initiatives, including R&D and processing technologies, which will form part of the follow-up to the above-mentioned training phase.

The Under-utilised Potential

The above discussion summarises the commercial potential of seabuckthorn and the experiences of China and the former USSR in harnessing the same. However, in other parts of the world, even when seabuckthorn is available as a native plant, the degree of its utilisation is far below that of these two countries and Mongolia, which also has large seabuckthorn plantations.

We conclude this section by referring to the use of seabuckthorn in other countries which (when contrasted with China and the former USSR) might give an idea of the vast potential of seabuckthorn, which remains under utilised. It will also increase the awareness about seabuckthorn potential in different countries.

Today, the largest seabuckthorn plantations are in the former USSR, Mongolia, and China, but more and more countries are establishing trial plots or growing this plant for different uses. Many countries, such as those of the Hindu-Kush-Himalayan Region, have rich resources but do not use them on a commercial scale. Along with dissemination of knowledge about seabuckthorn, it is believed that the HKH countries could establish more experimental plantations under cultivation for their own purposes.

Hippophae rhamnoides L., subsp. *sinensis* is mainly distributed throughout north, northwest, and southwest China. The fruit is rich in juice and oil and has currently more than hundred products and, because of its extraordinary tolerance to adverse circumstance, more than 330,000 hectares of new plantations have been established on the wastelands of China.

Hippophae tibetana is a dwarf species with a height of 10-40 cm, It is usually seen at high altitudes in the Himalayan mountains (above 3,500 m). Big, juicy fruits are often collected by Tibetan herdsmen and sometimes they are also used for medicine.

Hippophae rhamnoides L., subsp. *yunnanensis*, in appearance, is similar to *H. rham. L.* subsp. *sinensis* but it is mainly distributed in the area between South-west Sichuan and South-east Tibet and in North-west Yunnan as well. Because these areas are far from the cities and rather inaccessible, this subspecies has not been brought into use.

Hippophae salicifolia is the most promising species and is found in the southern Himalayan mountains from Kashmir to Bhutan, at altitudes of between 1,500-3,800 m. Its fruit contains more vitamins than other species. It is thorny, so is often harvested by hands or left to animals.

Hippophae neurocarpa is only found in the Qinghai - Tibetan Plateau of China at altitudes ranging from 2,800 to 4,300m. Its fruit is quite different from other types because it is characterised by a dark-grey colour, has little juice, and is small in size. The pulp and the seed, however, are rich in oil.

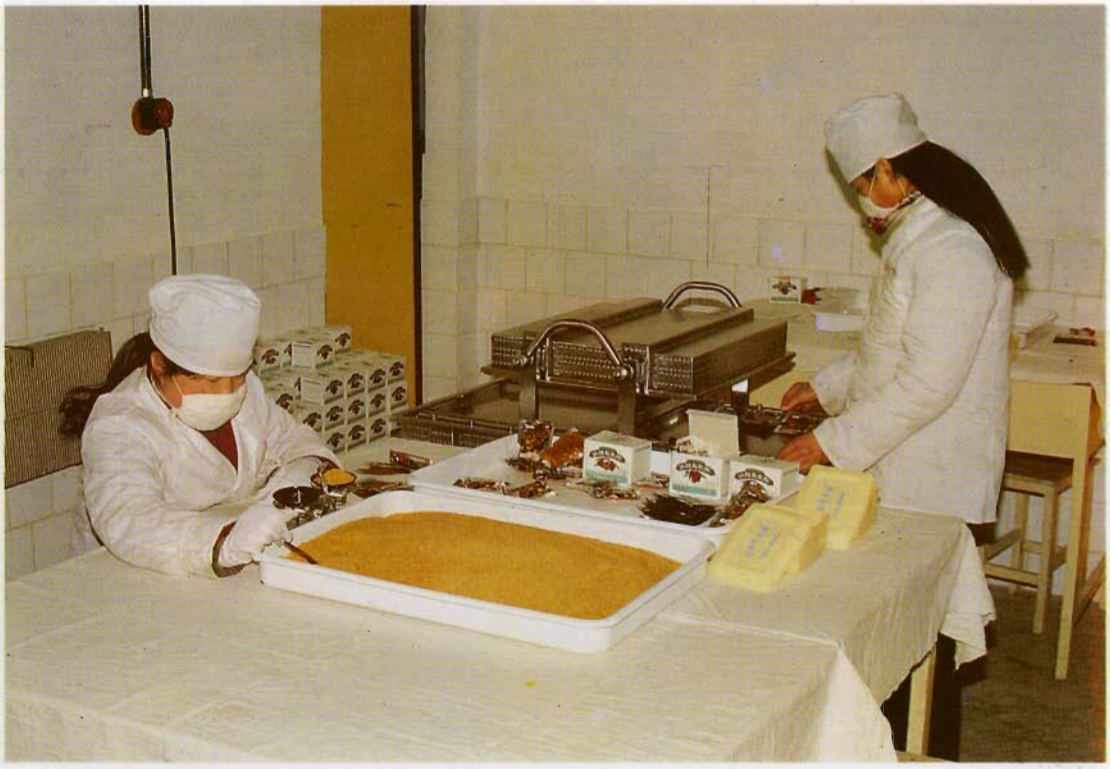
Hippophae rhamnoides L., subsp. *gyantsensis* grows on terraces and river banks at altitudes from 3,200 to 3,800m along the Yalu Tsangpo River in Tibet and Sikkim. The fruit has ridges on the surface and has less juice which indicates that this subspecies can resist drought.

It is estimated that seabuckthorn fruit can be used for making various products such as soft/hard/powdered drinks, jams, sweets, cosmetics, and medicines (more than a 100 products).

Seabuckthorn fruit is rich in flavones and is effective for treating cardiovascular diseases. A drug named Seabuckthorn Flavones Tablet was produced by the Pharmaceutical Factory of the West China Medical University, Chengdu, China.

Seabuckthorn raw juice has to be condensed to transport it to the terminal processing factories. In this picture, the workers of Xiaojin Seabuckthorn Beverage Factory, Western Sichuan, China, are operating the condensing machine.

Seabuckthorn oil refining workshop, Qin Yong Seabuckthorn Corporation, Shaanxi, China. Seabuckthorn oil is considered the most significant material for medicines.



Women workers (farmers) are packing Seabuckthorn Dried Emulsion that can be used for the treatment of coronary diseases, stenocardia, and to reduce blood fat and blood pressure.

Seabuckthorn bushes are either male or female. To procure more female plants, hardwood cutting technology is used to propagate seedlings. This is a one-year old hardwood cutting nursery (Zhang Zhixiang).

One-year old hardwood cutting seedlings (Zhang Zhixiang).

Seabuckthorn plantation established with hardwood cuttings. After two years the plants, which are only 60-100 cm high, begin to bear fruit.

The Loess Plateau is in the arid zone of the upper and middle reaches of the Huanghe River, China. With rugged topography and sparse vegetation, the fertile topsoil is washed away during monsoon. Each year there is a decrease of 0-2-1 cm in thickness. Due to soil erosion, the movement and undercutting increasingly infringes upon arable land. The control of soil erosion is the most urgent task in the region. The picture was taken in Lishin County, Shanxi Province (Huanghe River Conservancy Commission, China).

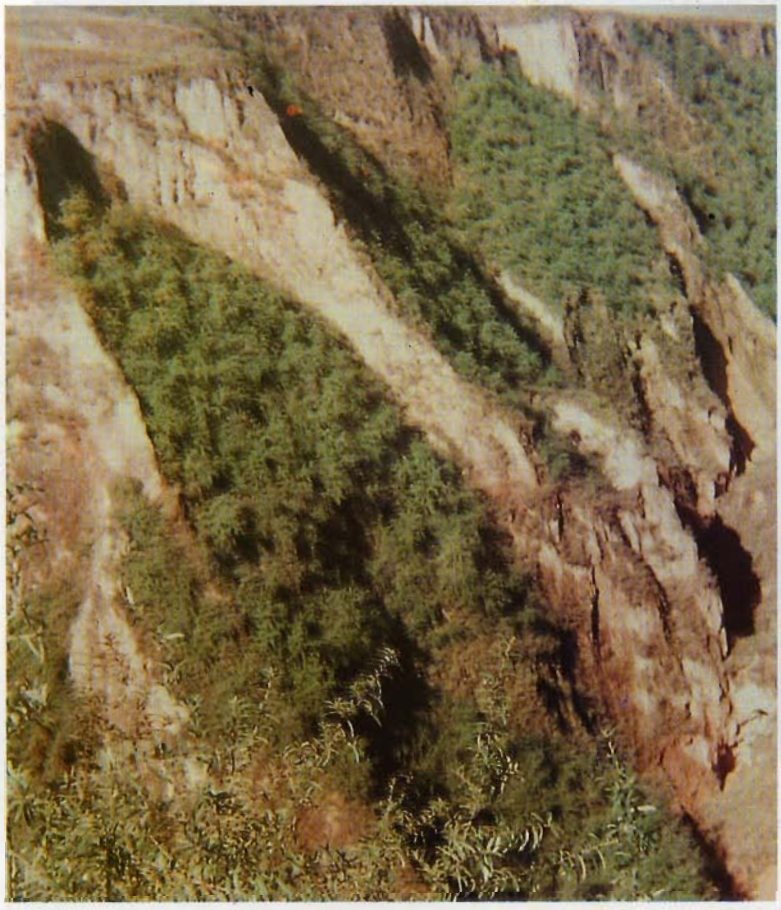
Stabilisation of mountain slopes is always a common problem in the mountain areas. Only those plants that are capable of fixing nitrogen, are good soil binders, provide good surface cover, and are significant as fodder, food, fuelwood, and even as medicinal plants would be advantageous for farmers. Seabuckthorn is just that kind of plant (Li Ming).

Air-seeding of seabuckthorn has proved to be a very promising method for afforestation. High speed, effectiveness, wider range, and low cost have emerged as advantages of this method (Liang Yimin).

After 3-5 years of air-seeding, the bare mountain slopes are covered with seabuckthorn bushes. Sometimes other species, for example milk vetch (*Astragalas adsurgens*), are mixed with seabuckthorn by strip air-seeding as used in the Loess Plateau, China (Cong Xinhai).

Because of its high quality biomass, seabuckthorn is a favourite green energy plant. Each hectare of six-year old artificial seabuckthorn forest can produce 18 tons of fuelwood.

When poplar or pine trees were mixed with seabuckthorn, both grew better than single pure stands. This is owing to the particular contribution made by seabuckthorn in increasing the moisture of the soil and thereby improving the soil fertility.

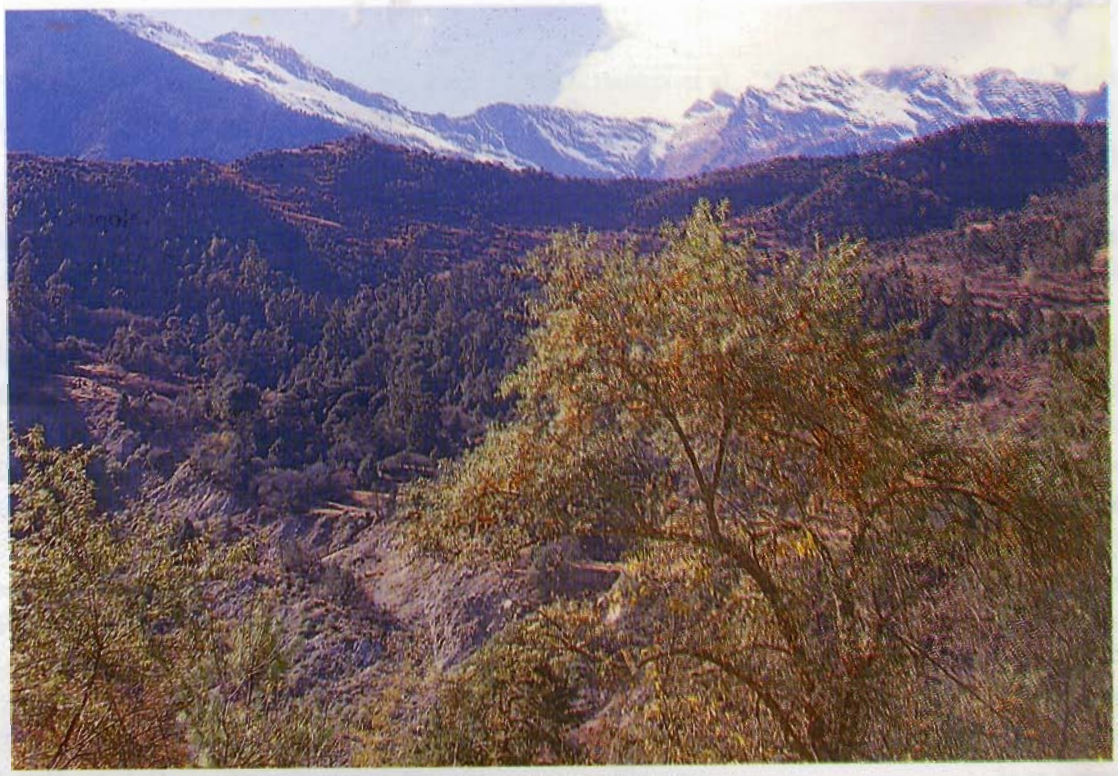


Once a seabuckthorn plant settles down in the soil, it can form dense bushwood in a short period through rapid multiplication of turions. This picture was taken in the gully area of the Loess Plateau, China. Seabuckthorn can even grow on slopes which have more than a 40° inclination (Li Ming).

The arenaceous land area of Inner Mongolia, China, where the weather is dry, cold, and windy, is considered to be an uncontrolled area. Many plant species fail to survive but seabuckthorn grows well there (Ao Fu).

A symbiotic mycorrhizal fungus, which is identified as *Flankia,* has been found on seabuckthorn roots. This symbiosis makes seabuckthorn form root nodules that can fix atmospheric nitrogen.

Usually, the ripe seabuckthorn fruit cling on to the branches for several months, and this enables many animals and birds to survive through winter. For example, the famous rare bird *Crosoptilon mantchuricum* is found to live on seabuckthorn fruit, which accounts for 35.4% of its food during winter.



Although most natural seabuckthorn forests are found along river banks, they can still grow well on the slopes of mountains if the rainfall is more than 400 mm. This photograph was taken from the edge of a coniferous forest in Southern Tibet.

The Hindu Kush-Himalayan Region is very rich in seabuckthorn resources which, in most cases, are not yet harnessed. In the near future, people will find that this plant can bring about multiple benefits in their daily lives. This is the Langtang Area of Nepal.

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