Sea Buckthorn (Hippophae rhamnoides L.): A Multipurpose Plant

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Review

Sea Buckthorn (*Hippophae rhamnoides* L.): A Multipurpose Plant

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Summary. Sea buckthorn (*Hippophae rhamnoides* L.) is a multipurpose, hardy, deciduous shrub, an ideal plant for soil erosion control, land reclamation, wildlife habitat enhancement, and farmstead protection. It has high nutritional and medicinal values for humans. The majority of sea buckthorn research has been conducted in Asia and Europe. It is a promising new crop for North America, and recently it has attracted considerable attention by researchers, producers, and industry.

Sea buckthorn (*Hippophae rhamnoides*) is a hardy, deciduous shrub with yellow or orange berries (Fig. 1) (Bailey and Bailey, 1978), which has been used for centuries in Europe and Asia. In ancient Greece, leaves of sea buckthorn added to horse fodder was well reputed to result in weight gain and shiny hair; thus, the Latin name '*Hippophae*' meaning shining horse (Lu, 1992). Sea buckthorn occurs as a native plant distributed widely throughout temperate zones between 27° and 69° N latitude and 7° W and 122° E longitude (Pan et al., 1989; Rousi, 1971) including China, Mongolia, Russia, Great Britain, France, Denmark, Netherlands, Germany, Poland, Finland, Sweden, and Norway (Fig. 2) (Wahlberg and Jeppsson, 1990; Yao and Tigerstedt, 1995). During the last decade, it has attracted considerable attention from researchers around the world, and recently in North America, mainly for its nutritional and medicinal value.

Sea buckthorn can be cultivated, but fails to set fruit, at an altitude of 3900 m (Rousi, 1971). In Russia, large, native populations grow at altitudes of 1200 to 2000 m above sea level (Eliseev and Fefelov, 1977). It can withstand temperatures from –43 to 40 °C (Lu, 1992). Sea buckthorn is considered to be drought resistant (Heinze and Fiedler, 1981; Kondrashov and Sokolova, 1990); however, most natural populations grow in areas receiving 400 to 600 mm of annual precipitation. Myakushko et al. (1986) recommended that sea buckthorn not be grown on dry soils, and Lu (1992) noted the need for irrigation in regions receiving <400 mm of rainfall per year. Some species or subspecies of sea buckthorn can endure inundation but cannot be grown on heavy, waterlogged soils (Myakushko et al., 1986), although they take up water rapidly (Heinze and Fiedler, 1981). Sea buckthorn develops an extensive root system rapidly and is therefore an ideal plant for preventing soil erosion (Cireasa, 1986; Yao and Tigerstedt, 1994). It also has been used in land reclamation (Egyed-Balint and Terpo, 1983; Kluczynski, 1979; Schroeder and Yao, 1995) for its ability to fix nitrogen and conserve other essential nutrients (Akkermans et al., 1983; Andreeva et al., 1982; Dobritsa and Novik, 1992)

Sea buckthorn was imported originally into Canada from Russia to the Morden Research Station, Agriculture and Agri-Food Canada, Morden, Manitoba, in 1938 (Davidson et al., 1994). Plantings were limited to ornamental landscapes, except in the provinces of Saskatchewan and Manitoba. The Shelterbelt Centre of the Prairie Farm Rehabilitation Administration (PFRA) of Agriculture and Agri-Food Canada (Indian Head, Saskatchewan) have been growing sea buckthorn for 30 years. It is one of the hardiest and most adaptable woody plants used in prairie conservation programs (Schroeder, 1988). More than one million seedlings have been distributed, and more than 250,000 mature fruit-producing plants grow on the prairies for enhancement of wildlife habitat, farmstead protection (Pearson and Rogers, 1962), erosion control (Cireasa, 1986), and marginal land reclamation (Balint et al., 1989; Kluchzynski, 1989; Schroeder, 1990).

Sea buckthorn can be used for many purposes (Fig. 3) and, thus, has considerable economic potential. A natural sea buckthorn habitat can yield 750 to 1500 $kg \cdot ha^{-1}$ of berries (Lu, 1992), shelterbelt plantings 4 to 5 $t \cdot ha^{-1}$ (Schroeder and Yao, 1995), and orchard plantings, up to 10 $t \cdot ha^{-1}$ (C. McLoughlin, personal communication). The vitamin C and E contents

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Fig. 1. Sea buckthorn berries.

are as high as 600 and 160 mg / 100 g of fruit, respectively (Bernath and Foldesi, 1992). Its pulp and seeds contain essential oil important for its medicinal value, such as superoxide dismutase activity in mice, and it has enhanced the activity of NK cells in tumor-bearing mice (Chen, 1991; Dai et al., 1987; Degtyareva et al., 1991).

Taxonomy

Hippophae belongs to the family Elaeagnaceae. Arne Rousi (1971) classified *Hippophae* (2n = 24) into three species based on morphological variations: *H. rhamnoides* L., *H. salicifolia* D. Don, and *H. tibetana* Schlecht. *Hippophae rhamnoides* was divided further into nine subspecies: *carpatica, caucasica, gyantsensis, mongolica, sinensis, turkestanica, yunnanensis, rhamnoides*, and *fluviatilis* Rousi. Liu and He (1978) described a fourth species, *H. neurocarpa* Liu & He, found on the Qinghai-Xizang plateau of China. These classifications were accepted generally by Lian (1988), but taxonomists still disagree on the precise classification of the genus.

Natural distribution

Sea buckthorn is native to Europe and Asia (Fig. 2). The total area of sea buckthorn in China, Mongolia, and Russia is about 810,000 ha of natural stands and 300,000 to 500,000 ha planted (Sun, 1995). Natural sea buckthorn stands are also widespread in Europe—on river banks and coastal dunes along the Baltic Coast of Finland, Poland, and Germany (Biswas and Biswas, 1980; Kluczynski, 1989; Rousi, 1971) and on the western coast and along the Gulf of Bothnia in Sweden. In Asia, sea buckthorn is distributed widely throughout the Himalayan regions including India, Nepal, and Bhutan and in the northern parts of Pakistan and Afghanistan (Lu, 1992).

Description

Sea buckthorn is a deciduous, dioecious shrub, usually spinescent, reaching 2 to 4 m in height. It has brown or black rough bark and a thick grayish-green crown. Leaves are alternate, narrow, and lanceolate with a silver-gray color on the upper side (Synge, 1974). This calcicolous species tolerates low temperatures, high soil pH of 8.0, and salt spray (Bond, 1983). The plant's extensive root system is capable of holding the soil on fragile slopes. Sea buckthorn can be planted in marginal soils due to its symbiotic association with nitrogen-fixing actinomycetes (Akkermans et al., 1983; Dobritsa and Novik, 1992). Roots of sea buckthorn also are able to transform insoluble organic and mineral matter in the soil into more soluble states (Lu, 1992). The plant rapidly spreads by rhizomatous roots, and will quickly colonize adjacent areas.

The sex of seedlings cannot be ascertained until they start to flower (Synge, 1974). Flower buds are formed mostly on 3-year-old wood, differentiated during the previous growing season (Bernath and Foldesi, 1992). The male inflorescence consists of four to six apetalous flowers. Pollen is released in large quantities when the air temperature reaches 6 to 10 °C. The female inflorescence usually consists of one single apetalous flower with one ovary and one ovule. The plant depends entirely on the wind for pollination: neither the male nor the female flowers have nectaries and do not attract insects.

Cultural management

Sea buckthorn normally is transplanted or directly seeded in the spring. Best growth occurs in deep, well drained, sandy loam soil with ample organic matter (Wolf and Wegert, 1993). In arid or semiarid areas, water must be supplied for establishment.

Information in the literature regarding the cultivation of sea buckthorn is limited. In Saskatchewan, Canada, seedlings planted in shelterbelts are often under stress due to lack of proper management. For commercial production in orchard-like plantations, cultural management is clearly important. Good growing conditions produce higher yield and good-quality fruit (Walhberg and Jeppsson, 1990; Wolfe and Wegert, 1993). Crop management of sea buckthorn should include fertilization and cultural practices such as spacing, pruning, irrigation, and weed control.

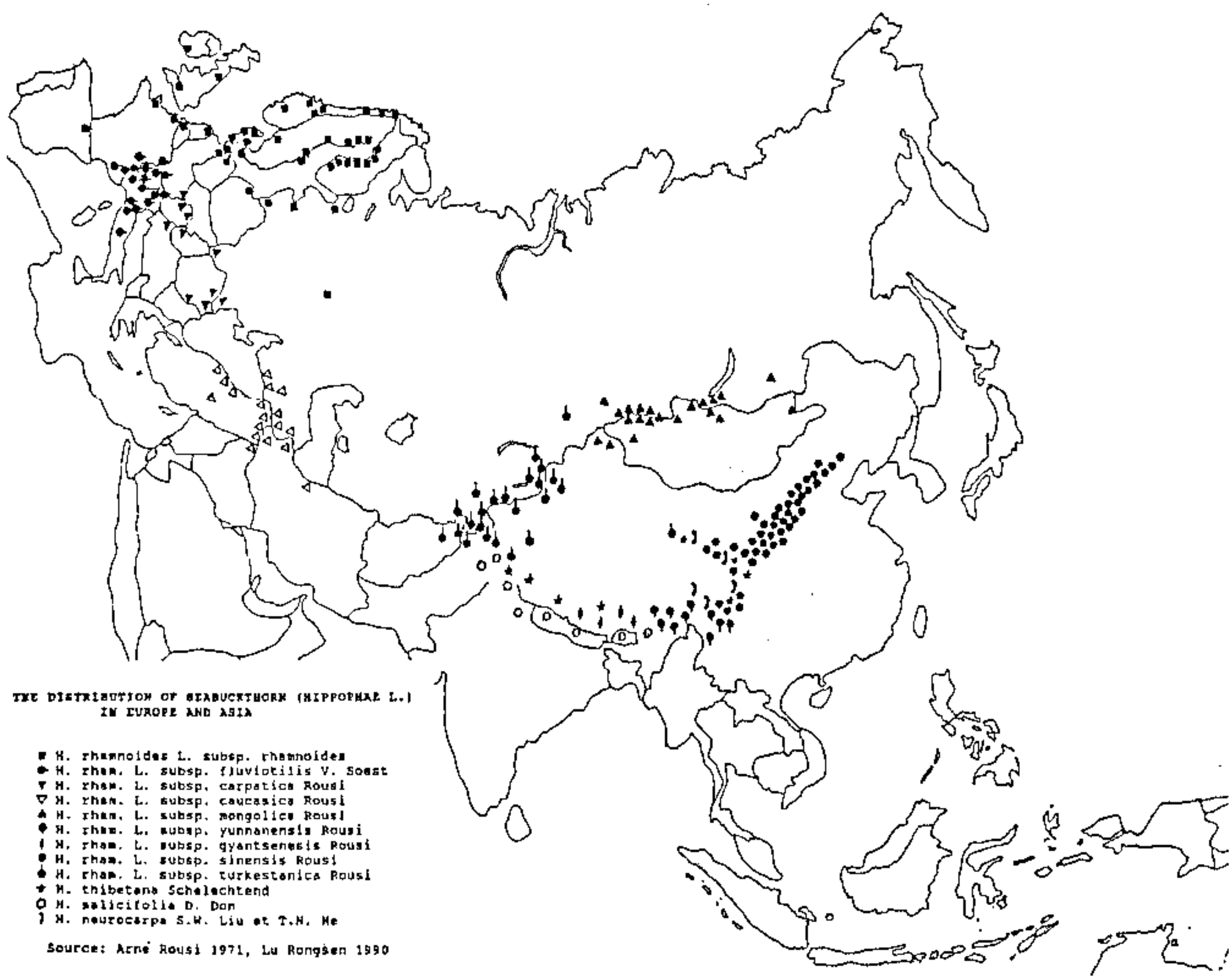
SOIL TEXTURE AND pH. In its natural environment, sea buckthorn plants are found on slopes, riverbanks, and seashores. Soil acidity and alkalinity, except at extreme levels ,are not limiting factors. In China, plants have been found in soils ranging from pH 5.5 to 8.3, although Lu (1992) reported that sea buckthorn thrives best at pH 6 to 7. Wolf and Wegert (1993) reported actinomycetes, which have a low tolerance for acid soil, living in symbiosis with sea buckthorn, which has a favorable range of pH 5.4 to 7.0.

Sea buckthorn is salt tolerant. An unconfirmed report indicated that 0.15% NaCl added to the growing media increased the growth of some varieties of sea buckthorn in the laboratory (Lu, 1992). Furthermore, soaking seeds for 24 h in 0.15% NaCl before sowing increased the number of vigorous seedlings.

PRECIPITATION AND SOIL MOISTURE. Most natural populations of sea buckthorn grow in areas receiving annual precipitation of 400 to 600 mm. For economic reasons, sea buckthorn orchards should be restricted to areas receiving a minimum of 400 mm of annual precipitation. Sea buckthorn is sensitive to severe soil moisture deficits, especially in spring when plants are flowering and young fruit are beginning to develop. Under extended drought situations (i.e., >30 centibars), young fruit may dehydrate or abscise (Lu, 1992). Buglova (1978) reported that weather conditions, especially precipitation, could affect fruit weight. In Belarus Academy of Science, Russia, Garanovich (1995) reported that irrigation was necessary during dry growing seasons. In an unconfirmed report, Lu (1992) indicated that the minimum soil moisture levels needed to cultivate sea buckthorn in medium clay loam, heavy clay, slightly sandy soil, and sandy loam were 70%, 80%, 60%, and 65% to 70%, respectively. Li (1990) reported that crown diameter and fruit yield increased 56% and 47%, respectively, in an irrigated plot with >70% soil moisture compared with a nonirrigated plot with soil moisture of 50% to 60%. These reports suggest that irrigation may be beneficial during periods of extended drought, especially during flowering and fruit development stages.

Soil fertility. Most of the soil fertility research on sea buckthorn was conducted in Russia and indicates that sea buckthorn, like any other crop, requires adequate soil nutrients for a high yield of good-quality fruit. Sea buckthorn responds well to phosphorus fertilizer, especially in soils low in phosphorus. Application of 600 to 800 $kg \cdot ha^{-1}$ of calcium superphosphate plowed deeply into the soil has been recommended (A. Bruvelis, personal communication). Garanovich (1995) reported that, in Belarus, a single winter top dressing with mineral fertilizers $100N–200P_2O_5–100K_2O$ ($kg \cdot ha^{-1}$) improved fruit size, yield, and quality. Martemyanov and Khromova (1985) indicated that best growth was obtained by applying peat compost at 60 $t \cdot ha^{-1}$ and 50 $kg \cdot ha^{-1}$ each of N, P_2O_5, and K_2O. In Siberia, 5-year total fruit yield increased by 23% when N, P_2O_5, and K_2O at 60 $kg \cdot ha^{-1}$ each were applied to a black calcareous soil (Predeina, 1987). Montpetit and Lalonde (1988) cautioned that nitrogen fertilization can adversely affect root nodulation and it delays the development of nodules after inoculation with *Frankia*. Similar results have been shown for other nitrogen-fixing woody plants (Mackay et al., 1987). Mishulina (1976) reported that foliar sprays with micronutrients—Cu, Mo, Mn, I, B, Co, and Zn—increased fruit weight by up to 34.5%. In China, application of 100 to 150 $t \cdot ha^{-1}$ of compost or 400 to 500 $t \cdot ha^{-1}$ of green manure is recommended before planting (Lu, 1992). Wolf and Wegert (1993) noted that precise fertilizer recommendations should be determined by soil sampling and analysis.

Fig. 2. The distribution of sea buckthorn in Europe and Asia.



TEMPERATURE. Sea buckthorn can endure the extreme minimum air temperature of –43 °C without sustaining long-term damage (Lu, 1992). Conversely, it can survive summer temperatures up to 40 °C, although Lu (1992) reported that temperatures above 30 °C burned leaves on newly planted seedlings. The latter observation may be the reason why efforts to introduce sea buckthorn from mountain areas to the plains of Asia often have failed.

SPACING. The largest sea buckthorn population in North America is in the Canadian prairies, where about 1000 km of field shelterbelts are planted annually (Schroeder and Yao, 1995). Two-year-old seedlings are planted for shelterbelts normally in one to three rows, 1 to 2 m apart within rows and 5 m between rows. Wolf and Wegert (1993) recommended a spacing of 1 m within the row and 4 to 4.5 m between rows to allow equipment access, with rows oriented in a north–south direction to provide maximum light. Beldean and Leahu (1985) reported that fruit yields are greatly influenced by exposure to sunlight, as sea buckthorn will not tolerate shade. High density orchards (1 × 1 m) are being considered in Europe to facilitate over-the-row harvesting equipment (Olander, 1995).

PRUNING. The purpose of pruning sea buckthorn is to train branches, promote growth, and facilitate harvesting (Albrecht et al., 1984). Savkin and Mukhamadiev (1983) reported that moderate pruning will increase the yield and fruiting life of the plants. Sea buckthorn grows up to 2 to 3 m in 4 years and forms its crown at the base of the main trunk. The crown should be pruned annually to remove overlapping branches, and long branches should be headed to encourage development of lateral shoots. In about the fifth year, the main trunk stops growing, and branches begin to grow from lateral buds. Mature, fruiting plants should be pruned to allow more light penetration if the bush is dense. To prevent sea buckthorn from premature senescence, 3-year-old branches should be pruned for rejuvenation (Lu, 1992). In Russia, pruning trials were carried out with sea buckthorn with the goal of creating a hedge to allow efficient mechanical harvesting (Savkin and Mukhamadiev, 1983). Similar work is underway in Germany (Gaetke and Triquart, 1992) and Sweden (S. Olander, personal communication).

WEED CONTROL. Weed control or vegetation management is very important in sea buckthorn plantings. Proper weed control promotes growth of newly planted seedlings. Cultivation in new plantings should not disturb the soil 8 to 10 cm below the surface so that shallow roots are not damaged (Gonchar and Saban, 1986). Herbicides for sea buckthorn plantations currently are being evaluated by the PFRA Shelterbelt Centre. Several chemicals are registered in Canada for weed control in sea buckthorn shelterbelts (Schroeder and Alspach, 1995). Albrecht et al. (1984) cautioned that only low concentrations of herbicides should be used. Low rates of simazine and lenacil applied to cuttings of sea buckthorn 10 days after planting and again 2 months later gave effective weed control and increased survival rate and growth (Shlyapnikova, 1985).

MALE : FEMALE PLANT RATIO IN THE PLANTING. For economical reasons, the ratio of male to female plants is important, as the number of fruit-bearing trees should be maximized. In Canada, sea buckthorn plants for shelterbelts are grown from seeds. Consequently, seedlings of unknown sex are planted, which results in an uneven distribution of male and female plants within each planting. This practice has long-term effects on total yield. To avoid this problem, the easiest approach would be vegetative propagation from promising mature plants of known sex. Recommendations for male : female ratio vary. Gakov (1980) considered that 6% to 7% male trees is adequate for pollination, whereas Albrecht et al. (1984) and Wolf and Wegert (1993) recommended 8% to 12%. The Siberian Institute of Horticulture in Russia recommended one male : female mixed row for every two rows of female plants. In the mixed row, every fifth plant is a male. Goncharov (1995) reported that this design gave significantly higher fruit yields compared to other designs. For effective pollination, the male variety should be cold resistant and have a long flowering period, an adequate amount of pollen, long-lived, and good vigor (Garanovich, 1995), since a pollinator had an appreciable effect on fruit weight, flavor, and ripening (Buglova, 1981).

HARVESTING. Berries persist on the branches all winter, perhaps due to the absence of an abscission layer. This results in an attractive ornamental plant in winter, but it is undesirable for harvesting. In Saskatchewan, Canada, the total labor cost for harvesting an orchard of 4 ha was estimated to be 58% of the total cumulative production cost over 10 years. In Asia, harvesting is still done by hand or with picking tools. This difficult and labor-intensive process requires about 1500 $h \cdot ha^{-1}$ (Gaetke and Triquart, 1993). Wolf and Wegert (1993) and Olander (1995) reported that difficulties associated with harvesting are major barriers to orchard production of sea buckthorn in Europe. Therefore, one of the most important factors for the success of sea buckthorn as a viable cash crop is a better and more economical harvesting method.

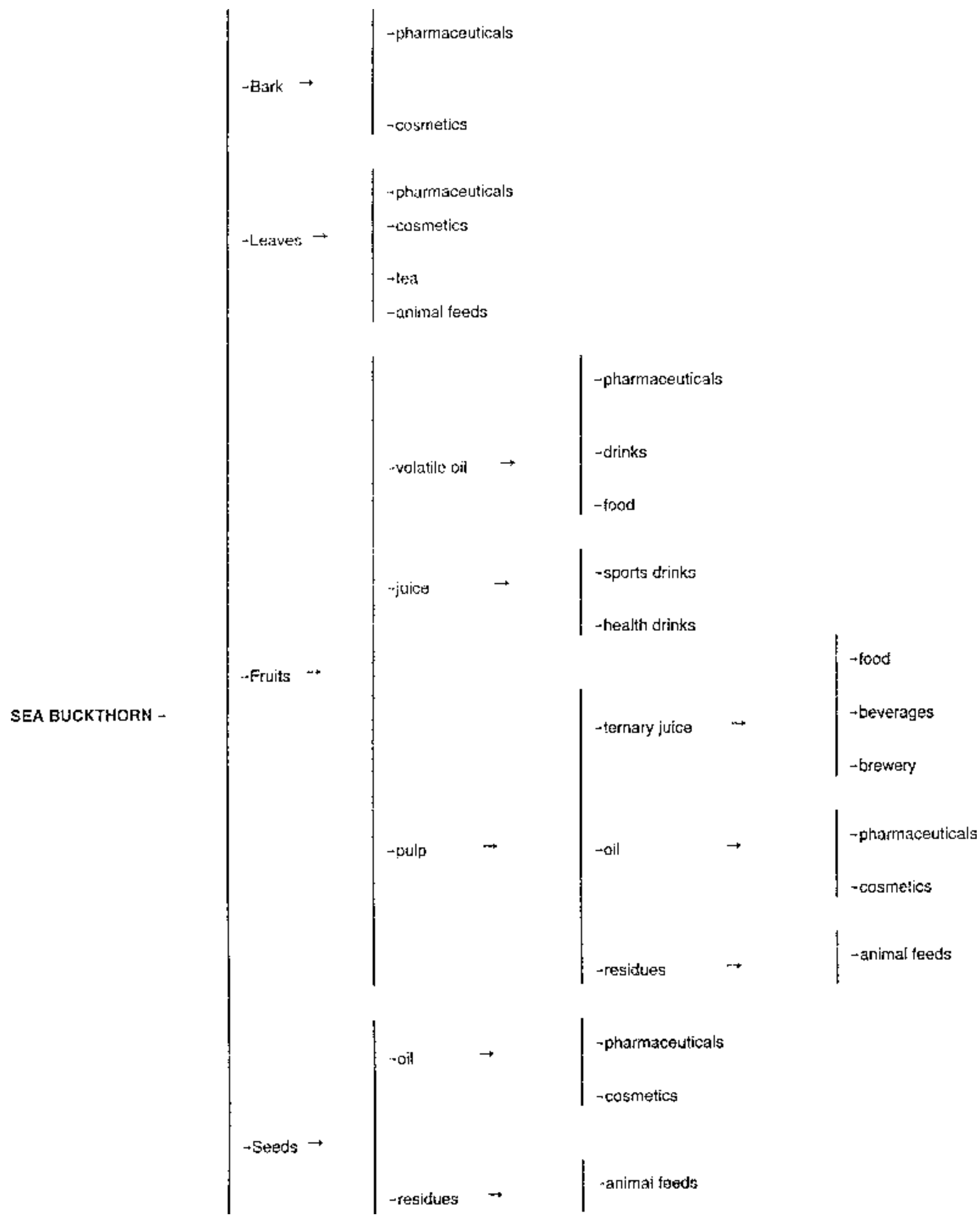
Koch (1981) harvested entire fruiting shoots with pneumatic shears. Botenkov and Kuchukov (1984) developed a device for hand-picking that consists of two hinged jaws with teeth and brushes. The development of mechanical harvesting techniques for sea buckthorn has attracted considerable attention. Savkin and Mukhamadiev (1983) designed a pruning machine to trim sea buckthorn into a hedge suitable for mechanical harvesting. Mechanical harvesters have been developed in Sweden, Germany, and Russia (Olander, 1995). However, most have disadvantages, such as fruit and bark damage and low efficiency. Harvesting equipment tested include shakers (Affeldt et al., 1988; Gaetke et al., 1991), vacuum suction (Varlamov and Gabuniya, 1990), and quick freezing (Gaetke and Triquart, 1993). Many harvesters are based on the principle of cutting off fruit-bearing branches (Gaetke and Triquart, 1992; Olander, 1995). Olander (1995) reported development of an over-the-row mechanical harvester that removes fruit-laden branches and extracts the fruit by shaking the branches in an axial direction.

In Germany, considerable work on mechanical harvesting of sea buckthorn has been completed. Wolf and Wegert (1993) reported techniques in which fruiting branches were removed and frozen overnight at –36 °C. Frozen fruit were removed by beating the branches. This method provided berries with excellent quality, but it was labor intensive (about 450 $h \cdot ha^{-1}$).

Gaetke and Triquart (1993) developed a harvester that works on the riddle principle. In this system, pruned branches are hand fed into the harvester, and the fruit is separated from branches and leaves by screen conveyors and fans.

The use of hormone treatments to facilitate fruit release is promising. Trushechkin et al., (1973) reported that Ethrel (ethephon) at 2000 mg·L^{-1} of water decreased fruit detachment force by 30%. Demenko et al. (1986a) suggested that the inability of ripe fruit to

Fig 3. Possible uses for components in different sea buckthorn plant parts.



abscise is caused by compartmentation of internal ethylene in seeds. Ethylene treatment induced the formation of an abscission layer, which could make harvesting more efficient (Demenko et al., 1986b; Demenko and Korzinnikov, 1990).

YIELD. Like any other crop, yield of sea buckthorn is affected by various factors such as genotype, soil conditions, annual precipitation, temperature, crop management, numbers of fruit-bearing branches, and time and methods of harvesting (Kondrashov, 1981). Yield data of sea buckthorn are scarce, since most fruit collection is from natural habitats, plantations for controlling soil and water erosion, and field shelterbelts. Wolf and Wegert (1993) reported yield of 5 $t \cdot ha^{-1}$ from an orchard plantation in Germany. Total yields reported in the literature from various regions were mostly estimates from experimental plots, cultivated under ideal conditions and management (I.M. Garanovich, personal communication). In Saskatchewan, Canada, fruit production in shelterbelts ranges from good to excellent, some selected plants producing 5 to 7 kg annually. This equates to yields of 4 to 5 $t \cdot ha^{-1}$. Canada Sea Buckthorn Ltd. (British Columbia) estimated an average of 3.25 kg / tree (6-year-old) collected from shelterbelt plantings (C. McLoughlin,, personal communication). Orchards with 4000 trees / ha and a 1:6 male and female ratio should yield about 11 $t \cdot ha^{-1}$. Detailed study is underway in Canada on the effects of crop management on yield.

Breeding and selection

There is a wide range of morphological diversity among sea buckthorn seedlings and mature plants within each subspecies, which is a good indication that there are excellent opportunities for plant improvement by breeding or selection for desired characteristics. Phenological observations have shown a clear gradient of growth rhythm and plant size corresponding to geographical distribution (Yao and Tigerstedt, 1994), which indicates that selection based on responses of plants to a specific growing region is important. This selection procedure is important in any country before sea buckthorn can be developed into a new viable crop.

Breeding sea buckthorn has been conducted for decades in Russia (Goncharov, 1995), Ukraine (Gladon et al., 1994), China (Huang, 1995), and Finland (Hirrsalmi, 1993). The first breeding programs began with mass selection from natural populations. This method is still common practice (Wahlberg and Jeppsson, 1990) but is gradually being replaced by hybridization (Huang, 1995; Yao and Tigerstedt, 1994). Polyploid breeding was reported in Russia where autotetraploids were induced by colchicine (Shchapov and Kreimer, 1988). There have been no reports of genetic engineering in sea buckthorn breeding.

Breeding programs exist in Sweden (Wahlberg and Jeppsson, 1990, 1992), Finland (Hirrsalmi, 1993; Yao and Tigerstedt, 1994), and Germany (Albrecht, 1993; Muller, 1993). Finnish and Swedish programs have concentrated on mass selection and hybridization. In Germany, the objective was to establish a collection of sea buckthorn representing the genetic spectrum of the species (Muller, 1993). A sea buckthorn breeding program has been initiated recently in Canada (Schroeder, 1995). It includes a long-term breeding population made up of progeny from diverse foreign wild collections and a short-term breeding population of superior individual plants selected from local plantations.

Important characters that need improvement in sea buckthorn are yield (Kondrashov, 1986a; Huang, 1995), fruit size (Buglova, 1978), winter hardiness (Kalinina, 1987), thornlessness (Hirrsalmi, 1993; Albrecht, 1993), fruit quality and early maturity (Yao and Tigerstedt, 1994), growth habit and long pedicel for mechanical harvest (Wahlberg and Jeppsson, 1990), and nitrogen-fixing ability (Huang, 1995). Kondrashov (1986a, 1986b) reported that average fruit weight and number of flower buds per unit length of branch are the most reliable traits for yield selection in the Altai region of Siberia. P.L. Goncharov of Russia (personal communication) pointed out that thornlessness could be selected in young seedlings; however, yield of each breeding line cannot be determined until at least the fourth year. Fruit size, thorniness, and hardiness reportedly are controlled by quantitative genes, and selection for one of these characters will not adversely affect others (Huang, 1995).

Propagation

The most common methods for propagating sea buckthorn are by seed, softwood or hardwood cuttings, and layering and suckers. Micropropagation using meristem culture has been investigated (Burdasov and Sviridenko, 1988; Montpetit and Lalonde, 1988) but is not commonly used.

SEEDS. Propagation from seed is relatively simple and produces a large number of seedlings at fairly low cost compared with other propagation methods. Storage affects seed viability. Smirnova and Tikhomirova (1980) reported that seeds of *Hippophae rhamnoides* lost 60% of viability after 4 to 5 years of storage.

Internal seed dormancy can be broken by stratification in moist sand for 90 d at 5 °C (Siabaugh, 1974). Seeds of sea buckthorn need high temperature to germinate. At 10 to 12 °C, Lu (1992) reported 13.2% germination after 47 d compared to 95% in 6 d for seeds at 24 to 26 °C. Vernik and Zhapakova (1986) also reported more rapid germination at 25 to 27 °C than at 20 °C. Good results also can be obtained by soaking seeds in hot water (70 °C) for 24 to 48 h, stirring frequently, then letting the water cool to room temperature (Lu, 1992). After soaking, seeds should be air dried before sowing. This technique is useful when sowing outdoors in spring or indoors in a greenhouse. At the PFRA Shelterbelt Centre, Saskatchewan, nonstratified seeds sown in late September at a depth of 1 cm and a rate of 100 seeds / m in rows 60 cm apart emerged the following spring with a 90% germination rate.

CUTTINGS. Cuttings produce rooted plants with the same genotype as the parent plant. The cuttings will bear fruit 1 to 2 years earlier than seed-propagated trees. Sea buckthorn can be propagated using either hardwood or softwood cuttings.

HARDWOOD CUTTINGS. The percentage of successful rooting from hardwood cuttings varies. Avdeev (1984) reported 86% to 100% success. Garanovich (1984) reported that, in the greenhouse under artificial mist, rooting success was 20% lower with hardwood cuttings than with softwood cuttings, but plants from hardwood cuttings attained heights of 90 cm by the end of the first growing season and could be planted out the next spring, whereas plants from softwood cuttings needed 1 to 2 years before transplanting to the field. Kondrashov and Kuimov (1987) reported that hardwood cuttings with apices removed were rooted successfully outdoors under plastic in pure sand or a sand and peat (1:1) mixture. In a separate experiment, they showed that 2-year-old wood, cut before budbreak and stored for 10 d in sawdust at 10 to 15 °C, gave 100% rooting in the field. Kuznetsov (1985) recommended taking cuttings before bud break, soaking in water (18 to 20 °C) for 7 days, and planting in the field with dark polyethylene mulch. In British Columbia, we obtained 90% rooting of cuttings taken in mid-March, stored in plastic bags at 0 °C until May, and placed in pots filled with peat in a heated propagation box (18 to 22 °C) indoors under fluorescent light. Lu (1992) reported that hardwood cuttings have not been used widely in nurseries.

Softwood cuttings. Avdeev (1976) reported that softwood cuttings collected from an 8-year-old tree in early spring, treated with IBA (50 $mg \cdot L^{-1}$) solution and planted in a peat and sand (2:1) mixture under mist, had 96% to 100% rooting in 9 to 11 d. Balabushka (1990) compared the effects of IAA, IBA, and chlorophenoxyacetic acid on rooting of sea buckthorn and found that IAA root dips were superior to the other hormone treatments. Ivanicka (1988) reported that, with or without IBA (0.1% to 0.3%) treatment, semi-lignified *Hippophae rhamnoides* cuttings rooted readily in a peat, polystyrene granules and sand (1–2:1 :0.5) mixture under mist in a plastic house. Timing of cutting collection is important. Kniga (1989) reported that, in the Kiev region of Ukraine, the optimum time was late May. Kondrashov and Kuimov (1987) reported that cuttings taken in late June from severely pruned branches (pruning was conducted in early spring before budbreak) successfully rooted (95% to 98%) in the greenhouse under mist.

Layering and suckers. Root cuttings also can be an effective propagation method for sea buckthorn (A. Bruvlis of Latvia, personal communication). Root cuttings were planted in pots and placed in a greenhouse for 6 weeks before being transplanted to the field at a spacing of 8 × 20 cm. Cuttings need to be acclimated to field conditions before planting by placing pots in a shady area for 1 week. The best results were obtained in sandy loam at pH 6 to 6.5 with medium humus content. Sea buckthorn easily produces suckers within a few years of planting, which is a good source for propagation (Kondrashov and Kuimov, 1987). The possibility of invasiveness by suckers to surrounding areas is high; routing cultivation and herbicide application are the best control measures for this potential weediness characteristics of sea buckthorn.

Multipurpose use

Environmental value. The wide adaptation, fast growth, strong coppicing, and suckering habits, coupled with efficient nitrogen fixation, make sea buckthorn particularly suitable for planting in degraded soils. In China, sea buckthorn has controlled soil erosion and water loss effectively and increased land reclamation. In addition, the harvest of sea buckthorn fruit has provided value-added industries to support the economy of rural regions of Asian countries. In Canada, sea buckthorn has proved highly beneficial for enhancement of wildlife habitat, farmstead shelterbelts, erosion control, and mineland reclamation.

Chemical components. Sea buckthorn fruit is rich in carbohydrates, protein, organic acids, amino acids, and vitamins (Bernath and Foldesi, 1992). Fruit contain 16 to 28 mg carotenoids / 100 g fruit, which can be used as food additives (Kudritskaya et al., 1989). Flavonoid content in leaves and fruit ranges from 310 to 2100 mg / 100 g air-dried leaf and 120 to 1000 mg / 100 g fresh fruit, respectively (Chen et al., 1991; Glazunova et al., 1984, 1985). Total volatile oil from the fruit is 36 $mg \cdot kg^{-1}$ (Hirvi and Honkanen, 1984), dry matter is 24.6% to 33.8% (Igoshina et al., 1987), and essential oil extracted from seeds ranged from 8% to 12% (w / w) (Lu, 1992).

Bounous and Zanini (1988) found that fruit maturity affects N, Ca, K, Na, Mg, Cu, Fe, Zn, Mn, titratable acidity, pH, moisture, glucose, fructose, and ascorbic acid content. Harju and Ronkainen (1984) reported that the trace elements found in liqueurs prepared from sea buckthorn included Al, As, Ca, Cd, Cr, Cu, Fe, K, Mg, Mn, Na, Ni, Pb, Rb, and Zn. Differences in chemical composition, carbohydrates, moisture, lipids, acids ,and vitamins A and C were found among the large and small fruit (Chen et al., 1991) and among subspecies (Lu, 1993) and geographic locations (Wang, 1990). Eliseev (1976) indicated that the levels of the biologically active substances such as ascorbic acid and carotene were higher in tree-like forms than in bush forms. Franke and Muller (1983) analyzed the fat of fruit and seeds and found 47%, 21% saturated fatty acids and 53%, 39% unsaturated fatty acids respectively.

Nutritional values. The value of sea buckthorn is often based on the nutritional value of its fruit (Magherini, 1986). Sea buckthorn berries are among the most nutritious and vitamin-rich fruit known. The fruit, including seeds, contain a large amount of essential oils and vitamin C (Centenaro et al., 1977; Novruzov and Aslanov, 1983). The vitamin C concentration in berries varies depending on species, geographical location, and physiological maturity (Bernath and foldesi, 1992; Zhou et al., 1991) from 360 mg / 100 g of berries for the European subspecies *rhamnoides* (Rousi and Aulin, 1977; Yao et al., 1992) to 2500 mg / 100 g of berries for the Chinese subspecies *sinensis* (Yao and Tiherstedt, 1994), which is higher than strawberries (205 mg vs. 64 mg / 100 g; Gontea and Barduta, 1974), kiwi fruit (300 to 1800 mg vs. 100 to 470 mg / 100 g), orange (50 mg / 100 g), and tomato (12 mg / 100 g) (Lu, 1992). Sea buckthorn is also high in protein, especially globulins and albumins (Solonenko and Shishkina, 1983), carotene (Kostyrko, 1990), fatty acids (Loskutovaet al., 1989), and vitamin E (Bernath and Foldesi, 1992). Fatty acids and vitamin E content are higher than in wheat, safflower, maize, or soybean (Lu, 1992). The leaves of sea buckthorn contain many nutrients and bioactive substances, such as urtica dioica, vaccinium myrtilis, and berberis vulgaris, which are suitable for animal feed (Morar et al., 1990).

Medicinal value. Medicinal uses of sea buckthorn are well documented in Asia and Europe. Clinical investigations on medicinal uses were initiated in Russia during the 1950s (Gurevich, 1956). Sea buckthorn oil is approved for clinical use in hospitals in Russia and in China, where it was formally listed in the Pharmacopoeia in 1977 (Xu, 1994). More than 10 different drugs have been developed from sea buckthorn in these countries and are available in different forms (e.g., liquids, powders, plasters, films, pastes, pills, liniments, suppositories, aerosols, etc.) and 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 damage (Abartene and Malakhovskis, 1975; Buhatel et al., 1991; Chen, 1991; Cheng et al., 1990; Dai et al., 1987; Kukenov et al., 1982). The most important pharmacological functions of sea buckthorn oil can be summarized as diminishing inflammation, disinfecting bacteria, relieving pain, and promoting regeneration of tissues. It also can be used for skin grafting, cosmetology, and treatment of corneal wounds. In an unconfirmed report from China, 350 patients treated with beauty cream made from sea buckthorn oil had positive therapeutic effects on xanthopsis, melanosis, senile skin wrinkles, and freckles (Zhong et al., 1989). Russian research reported that 5-hydroxytryptamine (hippophan) isolated from sea buckthorn bark inhibited tumor growth (Sokoloff et al., 1961). More recently, studies on the anti-tumor effects of sea buckthorn oil have shown positive results in China (Zhong et al., 1989).

Conclusion

Sea buckthorn is a unique and valuable plant species currently being domesticated in various parts of the world. The species has been used to a limited extent in North America for conservation plantings, but the use of food and nonfood sea buckthorn products has not been pursued. The plants are easily propagated and yields are relatively high, and production is reliable, with the potential market mainly in Europe. The main constraint to large-scale fruit production in North America is harvesting. This problem is being addressed through breeding programs and equipment development. Most sea buckthorn research has been conducted in Asia and Europe, specifically China, Russia, and Germany. Recently interest in western Europe and Canada has increased, and active research programs are underway.

Unique plant products, especially those with proven nutritional quality, are gaining popularity in North America. Development of a North American sea buckthorn industry presents a unique opportunity for agricultural production of a value-added crop on marginal land.

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