Sea Buckthorn (*Hippophae rhamnoides* L.) – Potential for A New Crop Species in North America

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EXECUTIVE SUMMARY

Sea buckthorn (*Hippophae rhamnoides* L.) has the potential to be a new crop species in North America. Sea buckthorn is a fruit-bearing, dioecious, and spiny shrub or small tree. The fruit of sea buckthorn are showy, drupe-like, and yellow to orange to red in color. Sea buckthorn is found in temperate climates and can thrive in temperatures as low as -43 C throughout its native range in Northern Asia and Europe. It can thrive on a variety of landscapes and has been historically used to prevent soil erosion with its extensive root system throughout Russia and China. Sea buckthorn has also been used in traditional medicine in these regions with a wide variety of products being made from the fruits of the plant. This is due to the many beneficial components present in the fruit, including the presence of vitamins, amino acids, antioxidants, and essential fatty acids. These nutritional and medicinal properties have prompted a growth of consumer interest in sea buckthorn berries as a potential food product. Due to this newfound interest, sea buckthorn has the potential to be established in North America, not only to produce berries but also as a possible plant in the landscape. Sea buckthorn can be established through seed propagation or by using softwood or hardwood cuttings from mature plants. Female plants propagated by seed fruit in 4 to 5 years whereas plants propagated from cuttings set fruit in 2 to 3 years. Sea buckthorn plants can be established within controlled environments before being transplanted to the orchard. This will allow plants to be prepared for commercial fruit production or can be sold on the retail market as seedlings or cuttings to be used in the landscape. Sea buckthorn may be a viable novel crop for the North American market. As it has been grown and commercialized in its native ranges, the potential for this crop to take off in the market is plausible due to its showy and nutritious berries and for use as an ornamental crop in the landscape.

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I. Taxonomy

Sea buckthorn (*Hippophae rhamnoides* L.) hails from the *Elaeagnaceae* family (Rousi, 1971). Sea buckthorn is a woody, deciduous, dioecious, fruit-bearing, and spiny shrub or tree (Beveridge and Li, 1999). Species within the genus *Hippophae* vary from a tree (*H. salicifolia*) to a dwarf bush (*H. tibetana*), with *H. rhamnoides* being somewhere in between, more so bush-like. *Hippophae rhamnoides* has been divided into many subspecies including: *carpatica, causcasica, fluviatilis, gyantsensis, mongolica, rhamnoides, sinensis, turkestanica,* and *yunnanensis*. *Hippophae rhamnoides* generally reaches 2 to 4 meters in height, though some in China have been seen to grow up to 18 meters. Its bark is rough, brown or black, with a thick gray to green crown (Bailey and Bailey, 1978). Leaves are alternate to nearly opposite, lanceolate, with a silver to gray color on the upper side and the under surface covered with peltate hairs (Rousi, 1971). Flowers are inconspicuous and apetalous, opening before the leaves. The fruit of sea buckthorn are drupe-like, consisting of a single seed surrounded by a fleshy hypanthium, and yellow to orange to red in color (Figure 1; Beveridge and Li, 1999).

Figure 1. Fruits of sea buckthorn (*Hippophae rhamnoides* L.). The fruits are berry-like, in clusters, and orange in color (Rongsen, 1992).

Sea buckthorn is found in a temperate climate and it can tolerate temperatures ranging from -43 C to 40 C (Lu, 1992). The plant can tolerate a high soil pH (up to 8.0), as it exists in coastal regions, where it is exposed to salt from seawater. Sea buckthorn has an extensive root system and is capable of holding onto hillsides (Beveridge and Li, 1999). This makes it a rather valuable plant, as its extensive root system makes it an ideal plant for preventing soil erosion, utilized in China and Russia for land reclamation (Yao and Tigerstedt, 1994). The plant spreads rapidly by rhizomatous roots, with suckers developing a few years after planting (Beveridge and Li, 1999). The plant is also valuable for its ability to fix nitrogen, however, the level of nitrogen fixation varies depending on external factors, such as climate and nutrient status of the soil

(Dobrista and Novik, 1992). Additionally, the roots of sea buckthorn are able to transform insoluble organic matter in the soil into more soluble forms (Lu, 1992).

As sea buckthorn is dioecious, the plant has male and female flowers on separate trees. Female plants begin to set fruit 4 to 5 years after planting from seed, or 2 to 3 years from cuttings (Beveridge and Li, 1999). The male and female flower buds open within the same time frame, around mid to late May. Male flowers release pollen in large quantities when temperatures reach 6-10 C, with female flowers being receptive for around 10 days. Flowers do not produce nectar to attract insects, so pollination relies solely on the wind. After pollination, fruit ripening occurs in around 100 days, typically in late August or mid-September. Sea buckthorn fruit has some ornamental qualities–in addition to the showy colors of the fruit, the plant shows diverse fruit shapes ranging from flattened spheres, ovate, cylindrical, to other irregular shapes.

II. Geographic Distribution

Sea buckthorn grows on a wide variety of landscapes, such as hills and hillsides, valleys, riverbeds, coastal regions, in small or isolated stands, or in mixed stands with other shrub or tree species throughout Europe and Asia (Figure 2; Beveridge and Li, 1999). Natural sea buckthorn stands in Europe are primarily found on riverbanks and coastal dunes including the Baltic Coasts of Germany, Finland, and Poland, along the Gulf of Bothnia in Sweden, and coastal regions of the United Kingdom (Rousi, 1971). The majority of *Hippophae* species in Asia can be found in the northern region of China, throughout the Himalayan region, and in northern Pakistan and Afghanistan (Lu, 1992).

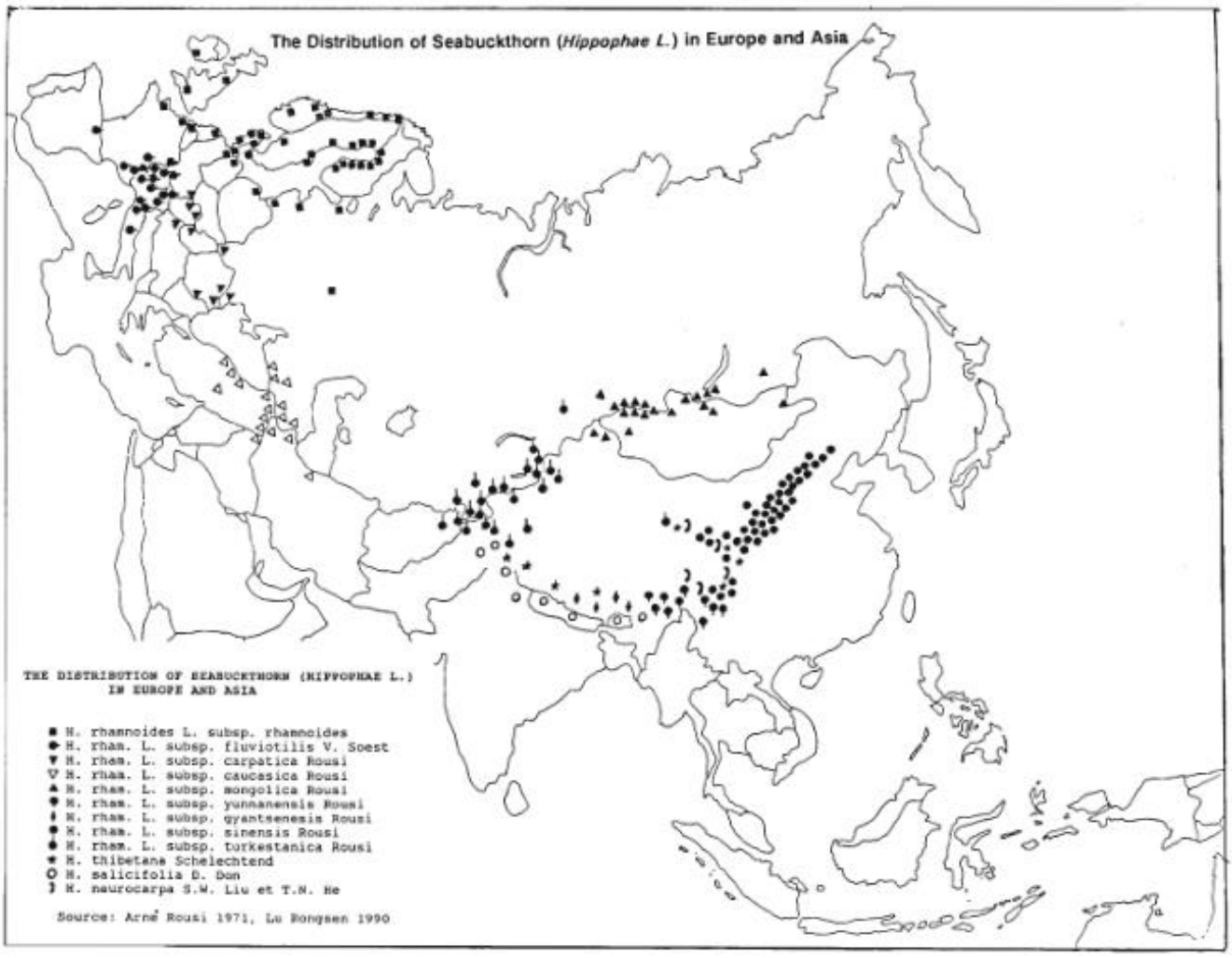

Figure 2. Distribution of sea buckthorn (*Hippophae* L.) species throughout its native ranges in Europe and Asia (Rongsen, 1992).

III. Growing Conditions

The cultivation of sea buckthorn is feasible, though requires certain growing conditions. At altitudes about 3900 meters, fruit fails to set (Rousi, 1971), with native populations of sea buckthorn in Russia occurring at altitudes of 1200 to 2000 meters. As this plant is seen in temperate climates, it can withstand extreme temperatures, so it may thrive in many environments. Sea buckthorn is considered drought resistant, although natural populations grow

in areas receiving around 400 to 600 mm of annual rainfall (Kondrashov and Sokolova, 1990). In regions receiving less than 400 mm of precipitation a year, irrigation is needed (Lu, 1992).

Sea buckthorn can be derived from seeds or cuttings (Beveridge and Li, 1999). When propagated from seeds, seedlings display variable growth form, height, and fruiting. Clones can also be utilized, being vegetatively propagated from cuttings or suckers. Clones are the preferred method of propagating sea buckthorn since this allows control of male to female ratios within an orchard, as this is a dioecious species that needs pollen from the males for fruit to set.

2. Crop Species History and Potential Uses

I. Domestication

The first sea buckthorn breeding programs began with a selection of natural populations (Beveridge and Li, 1999). While this method is still commonly utilized, it is being replaced by hybrid breeding (Yao and Tigerstedt, 1994). Sea buckthorn breeding has taken place for several decades in Russia, Ukraine, and China, with recent breeding programs starting in Europe and Canada (Beveridge and Li, 1999).

Sea buckthorn may be utilized as a potential new crop, though there are several characteristics that may need improvement including yield, fruit size, winter hardiness, fruit quality, and nitrogen fixing ability (Yao and Tigerstedt, 1994). In addition, breeding for long pedicels would be suitable for mechanical harvesting, though fruit skin toughness is an important characteristic when considering this technique, as fruit skin tends to get damaged at the pedicel end causing weeping after harvest. If planting in orchards, reducing suckers produced by the plant would help reduce labor costs (Beveridge and Li, 1999).

If left undisturbed, the berries remain on the branches all winter (Li and Schroeder, 1996). Berries are generally harvested by hand, though mechanical harvesters are also utilized.

After harvest, the berries must be inspected and cleaned. Damaged or diseased berries as well as stems, leaves, or other debris are removed. Sea buckthorn berries are known to emit a strong musky odor, detectable even in the field (Beveridge et al., 1999). Washing the berries prior to processing has been shown to reduce this odor. After washing, the berries are ready for juice extraction. The berries are pressed using several press types including cloth presses, serpentine belt presses, and screw presses.

II. Historic Uses

Sea buckthorn has been used in traditional medicine in both Asia and Europe (Suryakumar and Gupta, 2011). There is evidence to suggest the use of sea buckthorn as a health supplement in China, dating back to the Tang and Qing Dynasties. Sea buckthorn has also been used in traditional Mongolian medicine since the 13th century. In Central Asia, locals were known to use the fruits for treatment of skin diseases, hypertension, and gastrointestinal issues. Sea buckthorn was also used for the treatment of these ailments, as well as for asthma and rheumatism in the Himalayan region and Russia. The first clinical studies on the medicinal use of the plant were conducted in Russia in the 1950s, though China was the first country to recognize sea buckthorn as a potential medicine in 1977 (Olas, 2018). Various drugs have been developed in these countries using sea buckthorn and have been incorporated into powders, liquids, pastes, and aerosols (Li and Schroeder, 1996). Medicinal literature in China has described the use of the fruits for treating a variety of conditions including hepatic disorders, circulatory diseases, metabolic disorders, inflammation, fever, and cough (Kumar et al, 2011).

III. Potential Uses

There are a wide variety of products possible from the fruits of sea buckthorn. It has been found that juices, jams, and oils derived from the fruit have beneficial anti-inflammatory,

antioxidant, and anti-atherosclerotic effects, with these being attributed to the presence of phenolics, vitamins, amino acids, and phytosterols (Zeb, 2006; Basu et al., 2007). These nutritional and medical components present in the fruit have prompted a growth of interest in its potential as a food product (Ding et al., 2016). Oil can be extracted from the seeds and the pulp of the fruit, which contain high amounts of phytosterols and vitamins A and E (Zeb, 2006). Additionally, dry fruit and leaf extracts of sea buckthorn can be used for diet supplementation, though at much lower doses than oils (500-2000 mg daily compared to 2000-5000 mg). Oils have also had the potential to be used in commercial products, with a sea buckthorn oil-based mouthwash being a suitable alternative as a preventative agent for periodontal inflammation (Smida et al., 2019).

IV. Horticultural Distribution Chain

Sea buckthorn seeds should be harvested from fruits of wild species. These seeds should then be sent to breeding programs to develop seed products and vegetive products (cuttings) for producer companies. These seeds and vegetative propagules can be distributed to commercial growers to begin production of sea buckthorn. These plants can be produced for fruit production or for selling seedlings or cuttings on the retail market. For commercial fruit production, the processing of sea buckthorn begins with the harvest of berries in the late summer to early fall.

After berries are harvested, they can be sent to a processing facility and products may be established. These products include sea buckthorn juices, food dyes, and oils (Figure 3; Beveridge et al., 1999). Juices may be prepared from freshly pressed berries into a fruit drink or fruit juice mixed drink. Pigments or food dyes are created as a byproduct from the pressing of sea buckthorn berries, with the pigment being known as “sea buckthorn yellow”. For oils, once derived from pressed berries, can be used in a variety of cosmetic or pharmaceutical products.

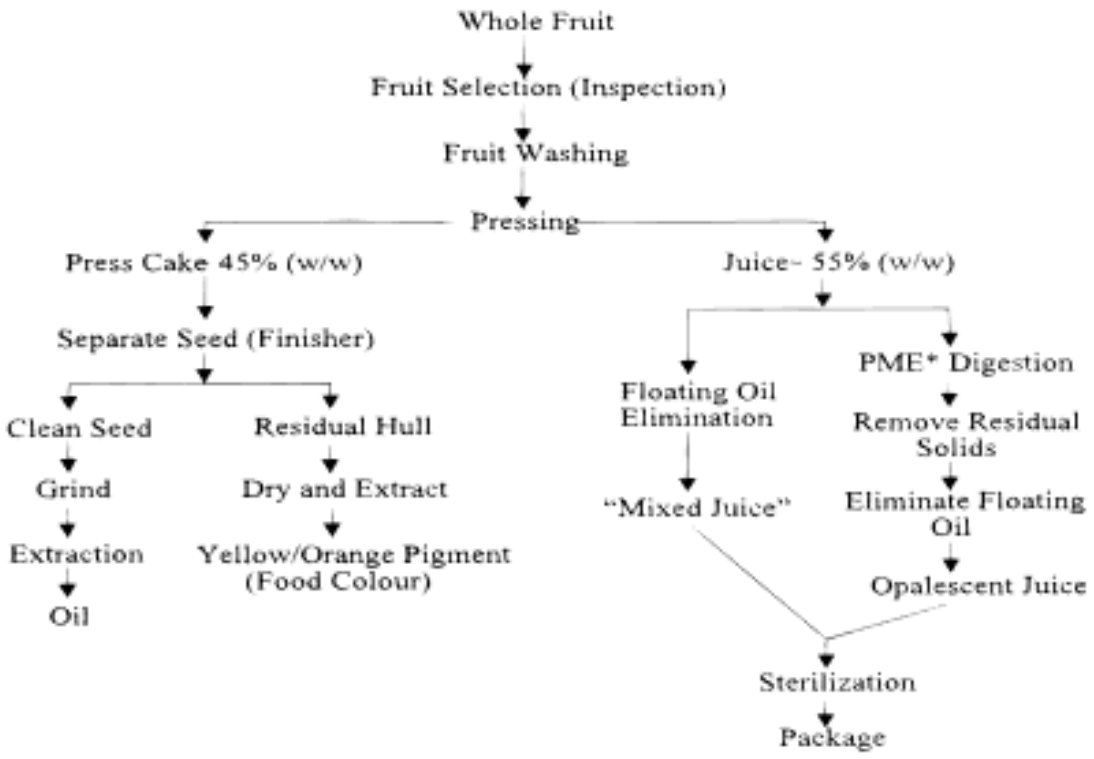

Figure 3. Processing of sea buckthorn berries: potential products include oils, food dyes, and juices (Beveridge et al., 1999).

3. Anticipated Cultural Requirements

I. Cultural Management

Sea buckthorn is vulnerable to soil moisture deficits, especially in the spring when plants are flowering, and fruits are developing (Li, 2002). In regions that are more arid, water must be supplied for sufficient establishment. Unless irrigated, sea buckthorn orchard plantings should only be grown in areas receiving a minimum of 400 mm of precipitation annually (Li and McLoughlin, 1997). Sandy loam soil on slight slopes is optimal, as sea buckthorn cannot tolerate a high water table or long term inundation, so this soil provides adequate drainage.

While soil acidity and alkalinity are generally not limiting factors, sea buckthorn does best at a pH of 5.5 to 7 (Li and McLoughlin, 1997; Li, 2002). Like other crops, sea buckthorn

requires adequate soil nutrients for a high yield and high-quality berries. Sea buckthorn responds well to phosphorus fertilizers, though nitrogen fertilizers can adversely affect root nodulation as it can delay the development of nodules, so the plant requires little nitrogen inputs. There is limited information regarding the nutrient deficiencies for sea buckthorn, though recommendations are given based on other crops (Table 1). Soil testing should be utilized to determine the pH levels before planting and the amount of fertilizer to be applied. Sea buckthorn performs well in soils with ample organic matter, so cover crops may be used, planting in the fall and plowed under in the early spring before sea buckthorn planting (Li and McLoughlin, 1997).

Table 1. Nutrient deficiencies that may be seen in sea buckthorn, symptoms, and recommended corrective treatments (Li and McLoughlin, 1997).

Symptom	Deficiency	Treatment
Foliage is pale green or yellowish and later leaf senescence and dehiscence are accelerated, plants are smaller than normal, leaf area is reduced	Nitrogen and/or phosphorus deficiency	Nitrogen and phosphorus fertilizer should be applied early in the spring in the forms of ammonium nitrate around 20g/m^2 and phosphate fertilizer (superphosphate) should be added in the fall at a rate of 20-30g/m^2. the rates should be based on the results of soil analysis.
Pale leaf colour, marginal chlorosis, scorch, shortening of stem internodes, death of the terminal bud	Potassium deficiency	Potassium fertilizer should be added with the phosphorus at 20-25g/m^2 of potassium chloride.
Terminal leaves normal, basal leaves marginal chlorosis with V pattern, this symptom occurs when potassium is high or soil is acid, especially in young, vigorous trees and defoliation begins from the base of shoots and progressively affects the leaves above	Magnesium deficiency	As required Custom blend
Delayed opening of flower and leaf buds in the spring, small chlorotic leaves, shortened internodes and little leaves along the shoot, reduced growth and small fruits	Zinc deficiency	As required Custom blend
Loss of chlorophyll and leaves become chlorotic, interveinal areas become yellow but the veins remain green, symptoms develop first on young leaves	Iron deficiency Iron deficiency can result when there is insufficient iron in the soil, sufficient but unavailable iron or sufficient and available iron that is not properly utilized in the plant	As required Custom blend

II. Planting Requirements

Sea buckthorn is primarily transplanted or directly seeded in the fall or spring. Seed propagation is relatively simple and produces many seedlings at a low cost compared with other propagation methods (Li and McLoughlin, 1997; Li, 2002). Prior to sowing, seeds should be soaked in hot water for at least 48 hours, with any floating seeds to be discarded. To prevent fungal infection on the cotyledons during emergence, the seeds can be soaked in a 10% bleach solution for 20 minutes prior to planting.

Seeds of sea buckthorn can be direct-seeded outdoors or seeded indoors for transplanting. When direct-seeding outdoors, emergence is greater when seeded at the soil surface compared to emergence rates at a depth of 1 to 2 cm (Li and McLoughlin, 1997). Soil should be misted periodically to prevent drying out. Seeds should begin to germinate in 5 to 14 days. Seeds should be spaced 1 m apart within the row and 4 m apart between rows (Figure 4). When sowing indoors, seeds can be sown in pots with sterilized soil in January or early February. There should be one seedling per pot, allowed to grow for around 3 months before transplanting in early May. Pot size should be 2” to 4” in diameter and up to 12” deep. When transplanting to the orchard, the root should be buried 6 to 8 cm to encourage the development of an additional tier of roots. New transplants should be watered weekly.

Figure 4. One year old plants in a nursery, spaced 1 m apart within rows and 4 m apart between rows (Rongesn, 1992).

Utilizing clones is an additional method of sea buckthorn propagation, produced using hardwood cuttings, softwood cuttings, or root suckers. Cuttings will bear fruit 1 to 2 years earlier than seed propagated trees (Li and McLoughlin, 1997; Li, 2002).

Hardwood cuttings should be taken from well-developed plants in the fruiting stage (Li and McLoughlin, 1997). These cuttings should be taken from the growth of the previous year during dormancy either in the late fall or in the early spring. About a week before planting, cuttings should be soaked in water until the beginning of root formation, ready to be transplanted once the roots are 1 to 2 cm long (Figure 5). Rooted cuttings can be directly planted outdoors in the orchard, though planting in pots under controlled environment for 1 to 2 months before transplanting will provide better results.

Figure 5. One year old hardwood cutting seedlings (Rongsen, 1992).

Softwood cuttings may also be utilized, as they have a high rate of success. These cuttings should be taken when the shoots become woody. The lower leaves should be removed, leaving 2 to 4 at the tip. The cutting should be dipped into rooting hormone then placed into a rooting media such as sand, perlite, or germination mix. These cuttings should be planted in pots for 1 to 2 months before transplanting into the orchard.

An additional propagation method for sea buckthorn is using root cuttings. Root cuttings are planted in pots in the greenhouse for 6 to 8 weeks prior to transplanting into the orchard in the spring. Sea buckthorn produces suckers within a few years of growth, which can be an easy source for propagation, though the success of this method varies on the genetics of the mother plant.

III. Additional Requirements

While sea buckthorn is a hardy plant, it has certain temperature and light requirements conducive to growth. Vegetation begins when the daily temperature reaches 5-7 C, and flowers at temperatures around 10-15 C (Li and McLoughlin, 1997). Sea buckthorn can only grow in well-lit and unshaded areas. Throughout all stages of development, the plant cannot tolerate shade. Seedlings or cuttings will die out if shaded by weedy plants during the first year of growth. Mature sea buckthorn will produce smaller crowns and have lower yields if shaded.

For maximizing fruit set, the male to female ratio should be considered (Figure 6). Sea buckthorn is a dioecious species, with the female plants bearing fruit. As sea buckthorn flowers are wind pollinated, it is essential to have a male plant for pollination to occur, and a greater number of female plants for greater yields (Li, 2002). If seedlings of unknown sex are planted, it can result in an uneven distribution of male to female plants. To avoid this, male plants can be removed and replaced with female plants or utilize vegetative propagation from plants of known sex (Li and McLoughlin, 1997). A recommended male to female ration can vary from 6-12%. An orchard seen in British Columbia with 2,500 trees/ha had a 1 male to 6-8 female ratio (Li, 2002). An estimate of an orchard with 4,000 trees/ha with a 1:6 male to female ratio should yield around 10 tons of fruit (Li and McLoughlin, 1997).

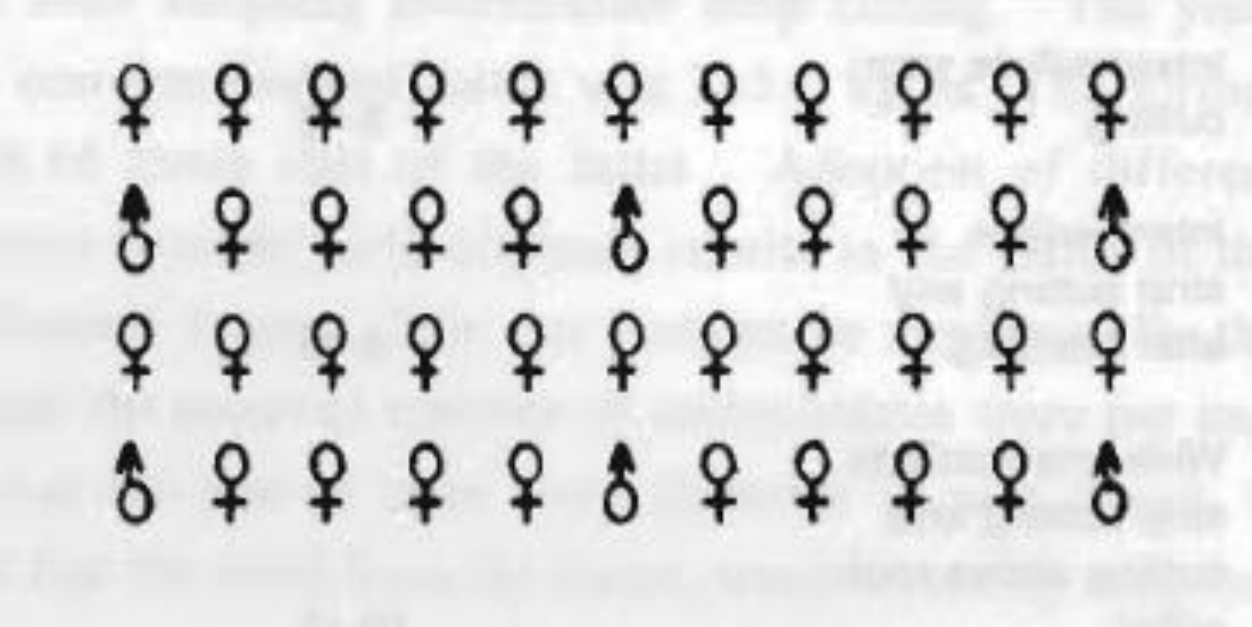

Figure 6. Example distribution ratio of male to female sea buckthorn plants in an orchard (Rongsen, 1992).

To maximize yield and reduce yearly fluctuations, moderate pruning is required. Sea buckthorn should be pruned to train branches, promote growth, and facilitate harvesting (Li and McLoughlin, 1997). Long branches should be headed to encourage lateral shoot development, and the crown should be pruned annually to remove any overlapping branches (Li, 2002).

4. Market Niche

I. Product Potential

Sea buckthorn berries and its products have been popular throughout its native ranges in Russia and China (Figure 7) and may have market potential in North America. The berries themselves have a characteristic bitter and sour taste, with a delicate aroma similar to a pineapple, and for this reason, sea buckthorn is also known as Siberian pineapple in Russia (Yang and Kallio, 2002). Its taste, nutritional properties, and health benefits make sea buckthorn

berries a valuable component in food products, cosmetics, and pharmaceuticals (Figure 8; Jaśniewska and Diowksz, 2021).

Figure 7. A variety of sea buckthorn products from China. These include soft drinks, jams, cosmetics, and candies (Rongsen, 1992).

Figure 8. Sea buckthorn products, including fresh berries, juice, and brewed tea (Jaśniewska and Diowksz, 2021).

Berries of sea buckthorn are among the most nutritious and vitamin rich fruits of any other fruit crop (Li and Schroeder, 1996). Sea buckthorn berries are rich in flavonoids and other antioxidants, vitamins, phytosterols (Table 2), polyunsaturated fatty acids, amino acids, and minerals (Beveridge et al., 1999). Vitamin C is quite high, with berries from *Hippophae rhamnoides* averaging 360mg/100g, which is comparable to strawberries, kiwis, and tomatoes (Jaśniewska and Diowksz, 2021). Berries are also high in other vitamins including Vitamin K and E. As these berries have been utilized in China and Russia for a variety of products, it is likely they may have success in North America. The nutritional properties in sea buckthorn

berries may be of interest to the consumer, especially when used to promote health and well-being.

Table 2. Major phytochemicals in sea buckthorn and their medical properties (Jaśniewska and Diowksz, 2021).

Sea Buckthorn Phytoconstituents	Medicinal Properties
Tocopherols	Act as antioxidants; minimize lipid oxidation; help to relieve pain
Carotenoids	Act as antioxidants; help in collagen synthesis and epithelialization
Vitamin K	Prevents bleeding; promotes wound healing; shows anti-ulcer effects
Vitamin C	Acts as an antioxidant; sustains cell membrane integrity; accelerates collagen synthesis
Vitamin B complex	Stimulates cell repair and nerve regeneration
Phytosterols	Improve microcirculation in the skin; show anti-ulcer, anti-atherogenic, and anti-cancer effects; regulate inflammatory processes
Polyphenolic compounds	Show antioxidant, cytoprotective, and cardioprotective effects; promote wound healing
Poly unsaturated fatty acids (PUFA)	Immunomodulatory, neuroprotective, and anti-tumor activity
Organic acids	Lower the risk of heart attack and stroke; show anti-ulcer effects; promote wound healing; anti-arthritic
Coumarins and triterpenes	Control of appetite; promote sleep, memory, and learning
Zinc	Strengthens the blood circulation; aids in cell proliferation; reveals anti-tumor effects; acts as a cofactor for enzymes; enhances utilization of vitamin A

While berries ripen in the fall, berries themselves are not as popular as the products they may be used in. It is possible to have seasonal products, such as seen in pumpkins in the fall. Growers and consumers may be interested in U-pick when sea buckthorn fruit ripen in the fall as a way for consumers to harvest their own berries and allows growers to pass on some of the labor costs while still being able to harvest leftover berries (Li and McLoughlin, 1997). Though there also may be year-round consumer interest in sea buckthorn products due to their many health and therapeutic properties. Additionally, sea buckthorn may be grown in the home garden, as it makes a great ornamental plant as well as provides berries for the owner in the fall.

II. Potential Limitations

While sea buckthorn has many potential uses, there are some limitations to commercial production. Fruit harvest is the most time-consuming process in growing sea buckthorn. Nearly all *Hippophae* species develop thorns, ranging from 2-5 cm on mature plants (Li, 2002). This makes it undesirable to harvest the berries by hand. While new cultivars without excessive thorniness are being tested, there currently are no cultivars without this trait. Another obstacle to overcome is the height of the plant. Sea buckthorn shrubs can reach 2 to 4 m in height, so it requires a proper pruning system to maintain a more manageable shape and height, which adds to labor costs (Li and McLoughlin, 1997).

Berries tend to persist on the branch throughout the winter due to the lack of an abscission layer, and firm berry attachment to the branch causes difficulties in harvest (Li, 2002). This adds to labor costs, with one estimation for harvesting a sea buckthorn orchard of 4 ha accounting for 58% of the total production costs over 10 years (Li and Schroeder, 1996). There are current studies underway to determine if ethephon, a compound used to reduce berry removal force in other fruit crops, can be effective in sea buckthorn cultivation, though there are currently no published recommendations for using ethephon (Li, 2002). As the berries can be difficult to remove, one method of harvesting involves cutting off the fruiting branch. However, as sea buckthorn fruit sets in the second year, harvesting by this means may not be economically sustainable for a majority of growers, as berries can only be harvested once every two years. The most successful method for harvest involves mechanical harvesting—shaking the individual branches of the plant to dislodge the berries, causing them to fall into a catcher placed around the base of the tree.

Postharvest handling and storage are important aspects that cannot be overlooked. Ripe berries must be harvested and quickly transported to a processing facility, then cooled to temperature around 4-6 C to slow growth of microorganisms (Li, 2002). If the berries are to be stored for more than a few days, it is best to freeze them. Frozen berries may be thawed and processed into products on demand. Juices made from sea buckthorn berries extracted by pressing or centrifugal techniques should be stored under refrigeration and require pasteurization for long term storage. While postharvest handling and storage for sea buckthorns can be accomplished following these general guidelines, it requires more planning than other fruit crops.

III. Sea Buckthorn on the Market

Sea buckthorn has the potential to be an excellent crop to be produced on the market. Sea buckthorn has bright and showy berries that could make it a great plant for the landscape. It can be used as a border hedge along the property, especially varieties that retain their thorns. The plant can also be used in preventing soil erosion on hilly landscapes, as sea buckthorn has an extensive root structure that has historically been used in land reclamation. Consumers will be very interested in the fruit of sea buckthorn, as the berries are high in many antioxidants, vitamins, and essential fatty acids. The crop can be sold as seeds or cuttings directly to retailers or other growers. As the establishment of mature sea buckthorn takes several years, producers, distributors, and growers should get started right away on establishing sea buckthorn as a new crop. Sea buckthorn can be anticipated to be launched on the market around 2028.

5. Production Information Guide and Crop Scheduling

I. Current Production Practices and Statistics

Sea buckthorn has been grown as a commodity crop in Russia, China, and Europe for decades. In China, sea buckthorn has been planted on over 500,000 ha, and has over 150

processing facilities to process the fruits that manufacture over 200 sea buckthorn-based products (Li and Schroeder, 1996). The Russian Institute in Moscow has been at the forefront of developing new cultivars since the 1950s, developing numerous sea buckthorn varieties used on orchards today (Pilat et al., 2015). On commercial orchards throughout Europe, there are several varieties that are primarily cultivated. These varieties include ‘Podarok Sadu’, ‘Avgustinka’, ‘Botanicheskaya’, and ‘Nivelena’ (Table 3) which primarily differ in crop productivity and the quality of fruit. Yields of these sea buckthorn varieties grown throughout Europe have found returns around 4-9 tons per ha.

Table 3. Popular cultivars of sea buckthorn grown on commercial orchards throughout Europe indicating fruit characteristics, harvest times, average vitamin C content, and average yield per plant (Pilat et al., 2015).

Cultivar	**Fruit Characters**	**Harvest Times**	**Vitamin C Content**	**Yield (per plant)**	
‘Podarok Sadu’	Ellipsoidal; orange to orange red	August-September	85–166 mg/100 g	15–24 kg	
‘Avgustinka’	Spherical, slightly ellipsoidal; orange	August-September	95–174 mg/100 g	12.5–20.5 kg	
‘Botanicheskaya’	Small, spherical; dark yellow	August-September	120-140 mg/100 g	Up to 2.5 kg	

‘Nivelena’	Spherical, yellow to orange	Mid-August	81 mg/100 g	Up to 35 kg	

The exact methods for production of sea buckthorn are scarce. There are known methods of propagation as well as general requirements for plant growth. Sea buckthorn has historically been grown using seed in China, though there is growing interest in growing from cuttings, which are primarily used throughout Europe (Li and Schroeder, 1996). Growth of sea buckthorn from seed can occur either outdoors or in controlled environments. Propagation by cuttings occurs in the greenhouse or in nursery fields, which are then transplanted to the field after roots appear or allowed to continue to grow in controlled environments. Propagation and growth of sea buckthorn can occur year-round, though should be scheduled to coincide with outdoor plantings to allow for establishment of the plants for fruit growth in subsequent years.

One challenge to current production practices is fruit harvest. In China, berries are primarily harvested by hand, though labor costs are lower than other cultivated regions such as Europe (Li and Schroeder, 1996). High labor costs can lead to high production costs over time. Mechanical harvesters are being investigated as a means to lower these expenses, especially with varieties of sea buckthorn with berries that are more easily detach from the branch.

II. Proposed Crop Production for the Future

The production of sea buckthorn should occur in USDA hardiness zones 3-7, as the climates in these regions are conducive to flower bud initiation and development in mature plants comparable to its native range and allow for stratification of seeds if sown directly outdoors (Li and Schroeder, 1996). Sea buckthorn has several propagation methods, of these include seed

propagation, and propagation through hardwood and softwood cuttings, which can be grown in controlled environments and have historically had success (Table 4). Sea buckthorn should initially be grown by seed to establish mature plants, with future production relying on these mature plants to receive hardwood and softwood cuttings to establish additional plants with known sex. Processing facilities in North America should be adjusted to accommodate the fruits of this new crop. As fruits are to be harvested in late summer or early fall, products utilizing sea buckthorn berries are to be expected on the market in late fall or early winter.

Table 4. Common propagation methods applied to sea buckthorn (Li and Schroeder, 1996).

Propagation method	**Advantages**	**Disadvantages**
Seed	Inexpensive; simple; low cost	Cannot distinguish sex until flowering (4-5 years); desirable characteristics may not be expressed; variation among seedlings
Hardwood cuttings	Inexpensive; produces genetically uniform plants with known sex; bears fruit quicker than seed propagation	Requires initial capital (i.e. established mature plants); initial propagation material may by limited; rooting not as successful as with softwood cuttings
Softwood cuttings	Inexpensive; high rooting success; produces genetically uniform plants with known sex; bears fruit quicker than seed propagation	Requires initial capital (i.e. established mature plants); initial propagation material may by limited

III. Production Guide and Crop Scheduling for Sea Buckthorn

Sea buckthorn plants can be propagated by seed, though this is not the preferred method for commercial production. Since sea buckthorn is a dioecious plant, the sex of the plant cannot be determined until maturity (i.e., when flowers set), which takes around 4-5 years for seed propagated plants, compared to 2-3 years for cuttings. Nevertheless, seed propagation of sea

buckthorn can be a simple way to produce numerous seedlings to establish an orchard for commercial production or perhaps for plantings in the home garden.

Before planting, seeds need to be stratified to break dormancy (Li and Schroeder, 1996). Dormancy can be broken by placing seeds in bags with moist sand and stored at 5 C for at least 90 days. This method of stratification is ideal if planning to transplant seedlings into the field in the spring, otherwise seeds can be directly sown outdoors in the late fall. In the greenhouse, these stratified seeds can be sown in 288 or 128 plug trays in January or early February using a perlite/peat moss germination mix. Seed depth is an important factor for seedling emergence. Seeds should be sown near the surface and no deeper than 2 cm, with 1 to 1.5 cm being ideal. Conditions in the greenhouse include a 16-hour photoperiod, temperatures ranging from 25-27 C, and a 70-90% relative humidity. To keep the soilless media moist, plants should be irrigated once a day, or when the top of the media becomes dry. Germination should occur in 7-21 days, and seedlings should be transplanted to a larger container (606 or 804 finishing trays, 4" pots) once true leaves appear around 4-6 weeks. Following germination, a starter fertilizer (10-52-10; N-P-K) should be applied with each irrigation for the first 3 weeks of growth. After this time, a complete fertilizer (20-20-20; N-P-K) should be used with each irrigation. These seedlings can then be transplanted into the field after growing in finishing trays or pots for around 90 days. Once transplanted to the field, seedlings should be spaced 1 m apart in rows and 4 m apart between rows. Do soil tests to make sure the soil pH remains around 6-7, liming if too low. Once in the field, irrigate as required, generally when soil is too dry if precipitation is low.

Table 5. Seed propagation guide for sea buckthorn. Includes plug size, weeks in plug, and additional requirements including pH, temperature, light, relative humidity, and fertilizer applications for each stage of growth.

CLASS/SERIES	SEED FORM	PLUG SIZE	PLUG CROP WEEKS	SEEDS/CELL	COVER SEED	DAYS FROM 50% TO MAXIMUM GERMINATION	INITIAL MEDIA
Sea buckthorn (*Hippophae rhamnoides*)	RAW	288/128	4-6	1	No	7	6.5-7.5 pH
STAGE 1	**STAGE 2**	**STAGE 3**	**STAGE 4**	**KEY TIPS**			
(t) 25-27°C (l) 1,000-2,500 f.c. (f) less than 100 ppm N (rh) 70-90%	(t) 25-27°C (l) 1,000-2,500 f.c. (f) less than 100 ppm N (rh) 70-90%	(t) 25-27°C (l) 1,000-2,500 f.c. (f) 200-400 ppm N (rh) 70-90%	(t) 25-27°C (l) 2,000-5,000 f.c. (f) 200-400 ppm N (rh) 70-90%	Keep media constantly moist, do not allow to dry out			

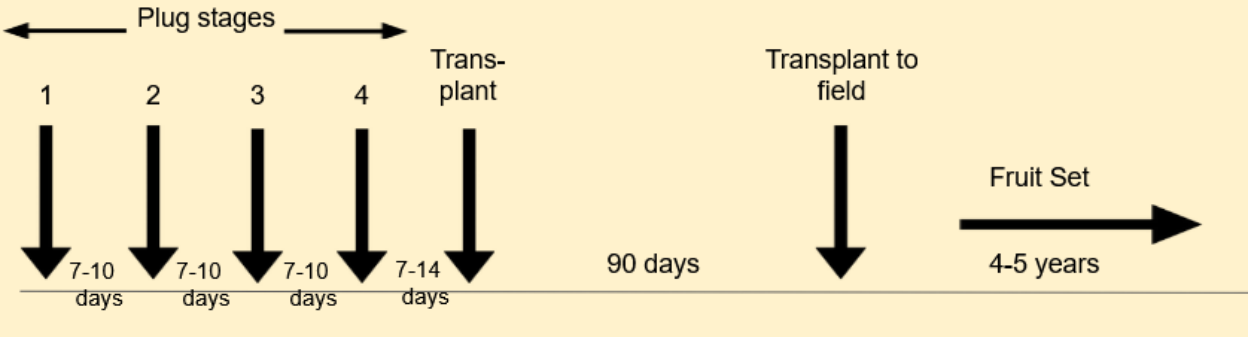

Figure 9. Schedule for sea buckthorn seed propagation. Stratified seeds are grown in 288 or 128 plug trays for up to 44 days in a controlled environment. Seedlings should be transplanted from plug trays to 606 or 804 finishing trays or 4" pots and allowed to grow for 90 days before being transplanted to the field or sold to retail markets. Once in the field, fruits will set in 4 to 5 years. Seeds should be sown in late February or March to coincide with outdoor plantings after around 44 days in plug stages and 90 days after transplanting to larger containers.

Rather than transplanting to the field for commercial growers, seedlings can be sold in 4" pots for retail markets. Plants can be sold from April to September and should be transplanted

outdoors before October to allow the plants to acclimate. However, growing sea buckthorn seedlings for the retail market may not be recommended, as the sex of the plant cannot be determined from seed propagated plants. This will make it difficult for the consumer to know which sex they are purchasing, as well as make it difficult to determine how many plants to buy, as there needs to be at least one male plant and one female plant to for fruit to set.

Another way of propagating sea buckthorn is through cuttings. Cuttings are preferred for commercial development of the plant as they fruit in 2-3 years (compared to 4-5 years with seed propagation) and the sex of the plant is known, which is important for the fruit set. There are two primary cuttings used for sea buckthorn propagation: hardwood and softwood.

Hardwood cuttings can be collected from mature sea buckthorn plants during the winter. Cuttings should be around 15 cm long, with the lower cut under the bud and the upper cut above the bud to allow for several nodes on the cutting. Having a clean cut is essential, as rough cuts do not heal well and are prone to decaying (Li and Schroeder, 1996). Cuttings should be placed in bundles then stored around 1 C. Before planting, cuttings should be soaked in water, leaving 2-3 buds above the surface for 5-7 days or until the buds swell. For rooting in the greenhouse, cuttings should be planted into 6" pots with a perlite/peat moss germination mix, leaving 2-3 buds above the substrate. After planting, the rooting medium should be kept moist with irrigation daily or every other day. Similar to seed propagation, the greenhouse should be set to a 16-hour photoperiod, temperatures around 25 C, and a relative humidity around 70-90%. Rooting should occur within 2 weeks of planting. After roots appear, plants should be fertilized with a complete fertilizer during irrigation. Hardwood cuttings should be grown in the greenhouse for around 6-8 weeks, and then can then be transplanted directly into the field or can remain in the greenhouse for around 60 days before transplanting outdoors.

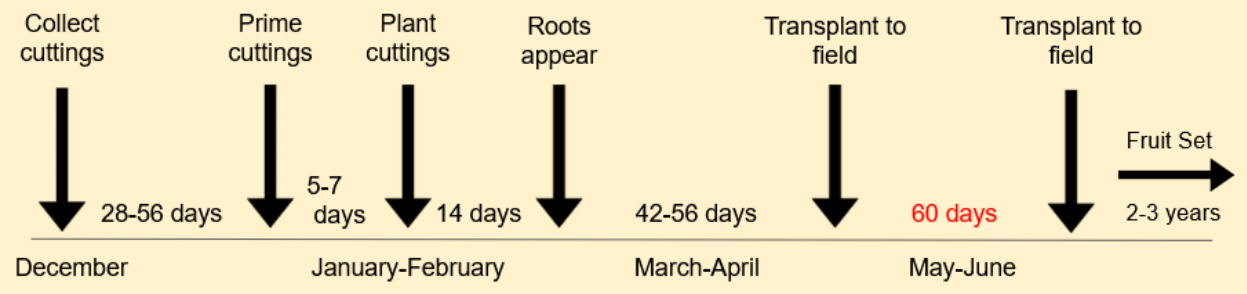

Figure 10. Schedule for sea buckthorn hardwood cutting propagation. Cuttings should be collected from mature plants around December then stored. Around January or February, cuttings should be prepared for propagation by soaking in water for 5-7 days until buds swell then placed in 6" pots. Roots will appear around 14 days then should be allowed to grow in a controlled environment for 42 to 56 days before being transplanted to the field in early spring (March-April). Plants can also grow for around 60 more days before transplanting to the field around May or June. Once in the field, fruits will set in 2 to 3 years.

Table 6. Propagation stages for hardwood cuttings of sea buckthorn, indicating the appropriate requirements to achieve successful propagation.

HARDWOOD CUTTINGS	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**
Description	Stick cuttings in soilless media	Root initials develop	Roots form	Further growth prior to transplant to field
Days in stage	0-7	7-14	14	14-56
Relative Humidity	70-90%	70-90%	70-90%	70-90%
Photoperiod	16 hr	16 hr	16 hr	16 hr
Root Zone Temperature	25°C	25°C	25°C	25°C
Air Temperature	25°C day. 5°C night	25°C day. 5°C night	25°C day. 5°C night	25°C day. 5°C night

Media Water Status	Keep media moist with daily irrigations	Keep media moist with daily irrigations	Keep media moist with daily irrigations	Keep media moist with daily irrigations
Rooting Hormone/PGRs	None	None	None	None
Fertilization	100-200 ppm N	100-200 ppm N	200-400 ppm N	200-400 ppm N

Other than using the greenhouse, hardwood cuttings can be rooted in a nursery field for commercial production. Cuttings should be planted in sandy soil with good sun exposure after soaking in water for 5-7 days. Before planting, the soil should be irrigated for a few days to provide adequate moisture. Soil moisture should be monitored throughout the rooting process, making sure it stays moist with daily irrigations. Cuttings in a nursery field are best planted in mid to late spring to allow for adequate growth. Towards the end of the growing season, the rooted cuttings can be transplanted to the field for commercial production. Once transplanted, these cuttings should bear fruit in 2-3 years. During this time, monitor the moisture and pH of the soil throughout the growing seasons, irrigating if the soil becomes too dry due to lack of precipitation and liming if the pH drops below 6.

Another way to propagate sea buckthorn is by using softwood cuttings. This method may be preferred over hardwood cuttings as this cutting type roots well (Li and Schroeder, 1996). Softwood cuttings can be collected from plants in late spring when shoots cease growing but before lignification occurs in the early summer. Softwood cuttings should be a similar length to hardwood cuttings, around 10-15 cm and with more than 2 nodes. Once cuttings are collected, immediately place them in moist paper towels to be planted soon after. Before planting, the cutting should be dipped in water, then in a rooting hormone (indole butyric acid). The cuttings can be placed in 4-6” pots or raised propagation beds filled with a peat/perlite germination mix. These beds should

be shaded and misted, as softwood cuttings need high relative humidity (around 90%) to stay turgid during the rooting process. Mists should occur every 30 minutes for at least 4 weeks. Softwood cuttings will begin to develop roots around 4-6 weeks, after which misting can conclude. After roots form, fertilize weekly with a complete fertilizer throughout the growing season. These plants can then be transplanted if outdoor conditions are conducive (ideally above 20 C daytime temperatures) or remain in pots for several months before being transplanted to the field in the spring. Similar to hardwood cuttings, these cuttings should bear fruit in 2-3 years once transplanted to the field. Monitor the moisture and pH of the soil throughout the growing seasons.

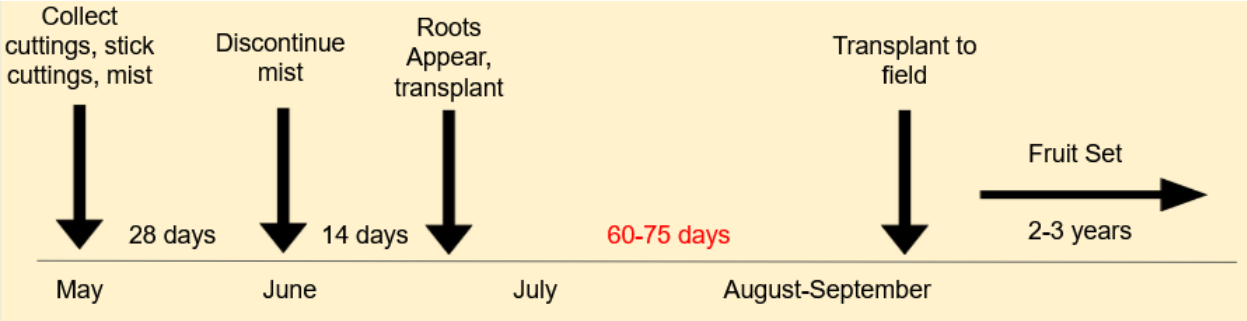

Figure 11. Schedule for sea buckthorn hardwood cutting propagation. On mature plants, softwood cuttings can be collected, wrapped in a moist towel, applied with a rooting hormone, then quickly planted in a controlled environment around May and before late June or early July. To keep cuttings turgid, mist will be applied for 28 days. Around 14 days after misting ceases, roots will appear and cuttings can be transplanted in the field around mid-July, Cuttings can also remain in controlled environments for up to 75 days before transplanting to the field in late August or early September. Once in the field, fruits will set in 2 to 3 years.

Table 7. Propagation stages for softwood cuttings of sea buckthorn, indicating the appropriate requirements to achieve successful propagation.

SOFTWOOD CUTTINGS	**Stage 1**	**Stage 2**	**Stage 3**	**Stage 4**
Description	Stick cuttings in soilless media	Root initials develop	Roots form	Further growth prior to transplant to field
Days in stage	0-14	14-28	28-42	42-112
Relative Humidity	80-100%	80-100%	80-100%	70-90%
Mist	Mist every 30 minutes for 10 seconds	Mist every 30 minutes for 10 seconds	Discontinue mist	-
Root Zone Temperature	25°C	25°C	25°C	25°C
Air Temperature	25°C	25°C	25°C	25°C
Media Water Status	Keep media moist through mistings	Keep media moist through mistings	Keep media moist through daily irrigation	Keep media moist through daily irrigation
Rooting Hormone/PGRs	Indole butyric acid	None	None	None
Fertilization	None	None	200-400 ppm N	200-400 ppm N

Hardwood and softwood cuttings of sea buckthorn may sell better in retail markets compared to seed propagated types. The benefit of using cuttings over seeds is that the sex of the plant is known, which can be addressed to the consumer on the label. Sea buckthorn cuttings may do well selling in a pack of two or three, as one of each sex is needed for fruit to bear in the female plants, though it should be noted that plants should each have their own individual pot (4” to 6”) rather than having two or three plants in a pot. Similar to seed propagated types, cuttings can be sold from April to September to be transplanted outdoors before October.

Once sea buckthorn plants are established in the field, fruit will be able to be harvested, either in 4-5 years for seed propagated plants or 2-3 years for cuttings. In orchards for commercial sea buckthorn fruit production, plants should be positioned to follow the 1:6 male to female ratio. Plants will require full sun, adequate irrigation (if precipitation is not sufficient), liming when soil pH falls below 6, and weekly to semi-weekly fertilizer applications during the growing season until maturity as well as after maturity. At this time, cuttings may be extracted from mature plants and prepared using the aforementioned methods for commercial growers or for sale in retail markets. When mature, female flower buds of sea buckthorn will open around mid to late May and be pollinated soon after, with fruit ripening occurring around 100 days after, around August or September (Li and Schroeder, 1996). Fruits are to be picked when ripe, determined by the berries having bright orange color and being soft (though not mushy) texture. Fruits can be harvested by hand, though using mechanical harvesters is more efficient and should be utilized for commercial production. These harvesters involve shaking the individual fruit-beating branches of the shrub with a fruit catcher around the base of the plant.

Sea buckthorn berries are easily ruptured, causing the fruits to be susceptible to spoilage from microorganisms (Li and Schroeder, 1996), so the fruits must be quickly transported to a processing facility and immediately cooled to temperatures around 6 C or less to slow the growth of these microorganisms. Once at the processing facility, sea buckthorn berries can be made into juices, extracts, or other finished products incorporating the fruit. The fruit themselves may also be shipped to the market, though it is not recommended as they are highly perishable. If sold in the market, sea buckthorn berries should be shipped and sold refrigerated or frozen.

IV. Crop Ideotype

Sea buckthorn (*Hippophae rhamnoides* L.) has the potential to be developed as a new crop species to be sold on the market. There are several components of sea buckthorn that would constitute the plant as ideal for future production: Sea buckthorn is a shrub to tree-like plant with a compact and upright growth habit. The plant is adaptable to various planting densities and responds well to pruning. The plant is vigorous, with a strong root system that can fix nitrogen and is useful for preventing soil erosion. The plant has a broad resistance to pests and pathogens. Sea buckthorn is tolerant to a wide range of soils and climate types, especially cold and arid regions, which makes it an ideal crop to grow in many hardiness zones, ranging from zones 3 to 7. Plants mature in as little as two years from cuttings and four years from seed. Mature plants bloom and are pollinated in the spring, with fruit harvest occurring in late summer to early fall. Sea buckthorn fruit can be harvested using a mechanical harvester or by hand. Fruits are large and plump berries with a showy bright orange color and tangy flavor, high in antioxidants, essential fatty acids, and vitamins. Fruit from sea buckthorn can be processed into many products, including juices, oils, and extracts to be used in food and cosmetic supplements. Overall, sea buckthorn is high yielding, disease resistant, adaptable to a wide range of environments, and produces large nutritious berries with many health benefits that can be utilized in a wide variety of commercial products.

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