# Research on Seabuckthorn (*Hippophae rhamnoides* L.) in Germany

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## ABSTRACT

Seabuckthorn (*Hippophae rhamnoides* L.) is a native plant in Germany with 3 subspecies. The bigger birds (Turdus pilaris, Turdus merula, Turdus viscivorus, Nucifraga caryocatactes and Bombycilla garrulus) play an important role in the distribution of Hippophae seeds. Seabuckthorn plants were also used for stabilisation of erosion, which had endangered soils at different places in Germany. Recognizing their ability to fix nitrogen from soil air, Hippophae was planted as a pioneer plant for different locations especially for recultivation of industrial dumps and dumps from coal mining. During the last century Hippophae had also been planted for its ornamental value mainly by the silver colored leaves and the orange colored berries. Askola, Dorana, Frugana, Hergo and Leikora are some of the improved forms devevloped. The planting of the shrubs is carried out in rows with a distance of 4.0 m to 4.5 m to enable harvesting by machines. The distances within the rows between the plants are 1.0 m to 2.0 m, depending upon the cultivar. At the same time, a harvesting machine was developed rattling the berries from small fruit branch pieces (about 1 cm) by vibration. The fruit harvest is carried out only in a two years rotation.

**Key words:** Seabuckthorn distribution, genetic resources, cultivars, spacing and harvesting machine.

## DISTRIBUTION

*Hippophae rhamnoides* L. is a native plant in Germany with 3 subspecies. Hippophae rhamnoides ssp. rhamnoides (syn. H. rhamnoides ssp. maritima) is distributed along the coast sides of north sea and Baltic sea. Homogeneous populations can be found on the islands, Hiddensee and Ruegen within the Baltic Sea. At various places of Baltic sea coast also different populations were used as excellent wind resisters and for biological protection of coast. *Hippophae rhamnoides ssp. fluviatilis* is distributed mainly outside of Germany, from Suisse to Italy and France. Only the northern part of its population can be found in South Germany (near river Rhine and in the Bodensee area). The third subspecies *Hippophae rhamnoides ssp. carpatica* is distributed between the rivers Danube and Isar, also in the southern part of Germany.

It is assumed that *Hippophae rhamnoides* came to Middle Europe before the late ice-ages. The first plants of the present populations came to these areas between 13,000 and 9,800 B.C. It is known from pollen analyses that seabuckthorn was wide spread over Middle Europe at the end of this period. Thus this period is named as willow-seabuckthorn-juniper period (Salix- Hippophae-Juniperus period). As a result of the beginning of natural forest formation, the plants of seabuckthorn were displaced more and more to full sunny places by competition of various woody plants. Hippophae rhamnoides is a very shade sensitive plant. Only along the coast sides and in the gravel beds and at embankments of the rivers rising in the Alp mountains, the plants found suitable places for growing far away from competition with other woody plants. Among the coast sides, these are often small islands without any woodlands. The natural propagation of Hippophae is by seed. Various birds eat the berries and excrete the seeds. From recent studies, it is known that 42 bird species eat the berries of seabuckthorn in Middle Europe. Especially the bigger ones are important for distribution of Hippophae seeds (Turdus pilaris, Turdus merula, Turdus viscivorus, Nucifraga caryocatactes and Bombycilla garrulus). These birds can eat the whole fruit. Already the germinating plants will grow with suckers and stolons, forming large homogeneous populations after a few years.

## PROPAGATION

By forming suckers and stolons, seabuckthorn plants can protect soils against erosion. For maritime exposures, Hippophae has been used for a long time. Already during the 18th and 19th century seabuckthorn had been planted for this purpose. Protecting the natural populations at the Baltic sea coast against using the plants as firewood several orders had been published during the last century. Some years later seabuckthorn plants were also used for stabilisation of erosion, which had endangered soils at different places in Germany. Recognizing their ability to fix nitrogen from soil air, Hippophae was planted as a pioneer plant for different

locations, especially for recultivation of industrial dumps and dumps from coal mining. Partially these plants grew under extreme soil conditions for example on very alkaline carbide lime containing soils.

In some regions, Hippophae was also planted along the highways (German autobahn), where the shrubs provided a supplementary ornamental value by the orange colored fruits. Some of these plantations grew up very quickly by stolons and seed, but later they were displaced by competiting shade trees. Only small remainders can be found there presently. Seabuckthorn plants changed the soil conditions at these locations by nitrogen accumulation in a suitable way for the growth and development of various following trees and shrubs. Using Hippophae as a pioneer plant for devastated and erosion endangered soils, all native subspecies in Germany had been planted. Cross pollination occurred and as a result inhomogeneous mix populations were borne. A great amount of seeds for commercial nursery production was collected there, containing many plants with hybrid characters. This heterogeneous plant material provide the genetic pool for later breeding. During the last century Hippophae had also been planted for its ornamental value mainly by the silver colored leaves and the orange colored berries. But the forming of fast growing stolons had proved to be a problem using it as ornamental shrub in small gardens and parks. More often the fruit bearing branches of the female plants were used as floristic material. In some regions this is a very old tradition. While cutting of fruit bearing branches from the wild caused a decrease of Hippophae populations in some regions during former times, presently the collection of floristic material is possible from large plantations.

## EXPLORING THE NATURAL GENETIC RESOURCES

In 1940, Griebel and Hess discovered the very high vitamin C content of Hippophae fruits. For that reason, seabuckthorn became a great importance for the plant breeders in Germany. Already during the second world war, the berries were used as a supplementary vitamin support, advised by Hoermann (1941). Therefore the first aims covered the registration of all natural Hippophae populations and plantations in Germany, the commercial harvest of the fruits and the installation of new plantations on waste lands. At the same time, the first research work began on genetic variability and breeding of Hippophae. Darmer (1947) and Stocker (1948-49) dealt first with genetic variability of natural populations along the German coast sides and in the Alp Mountains. Both of them found a genetic caused variability resulted in morphological characteristics as size of leaves, fruit size, fruit shape and fruit color but also in the content of several substances in the berries, for example, the content of ascorbic acid. Darmer studied the variability at small homogeneous locations with native populations of the subspecies rhamnoides at the island Hiddensee within the Baltic sea. During his investigations, he found 7 different yellow colored and 4 different red colored forms of fruits. In addition, he found shrubs with different fruit shapes, mainly with elliptic, but also with globular, cylindrical, pear-shaped and drop-shaped berries. Furthermore, he distinguished between low growing shrubs (max. 2 m height) with small leaves, medium-sized shrubs with 3 m height and large-growing shrubs with 4-5 m height. These morphological and growth characteristics are also caused genetically. In general, plants of the subspecies rhamnoides show a more compact habit with strong and thick branches. Both Danner and Stocker suggested to focus attention on breeding of Hippophae rhamnoides for increasing the content of ascorbic acid. Later Eichholz made an important contribution by registrating and evaluating of established populations in East Germany.

During 1945 and 1990, the division of Germany had an influence on the research work and breeding activities of seabuckthorn. In west Germany, products made from seabuckthorn berries were only sold as "eco-food" or "bio-food" in health food shops. But in east Germany, there was a great interest in offering more products like natural juice, soft drinks, jams and jellies from inland plantations caused by the shortage of import fruits. Breeding of Hippophae in east Germany was mainly focused on the content of vitamins, fruit acid and the yield of fruits. One of the preconditions for the following cloning of single plants and the selection of clon-type cultivars was the development of intensive propagation methods. Already Eichholz dealt with the problems of generative and vegetative propagation of seabuckthorn in 1957. But only after developing automatically controlled mist and fog systems and by using polythene tents in cutting propagation, an intensive vegetative propagation of Hippophae became possible. In the Breeding Station of the Nursery in Berlin-Baumschulenweg, two supplementary technologies were developed:

1. Cutting propagation in polythene tents with automatically controlled mist beds and

2. Hardwood cutting propagation in polythene tents and the open ground.

An important precondition for both technologies is the maintenance of stock plants in the nursery. These stock plants have to be pruned back annually in winter time to provide a great amount of cuttings with best rooting potential.

## SELECTION AND BREEDING

1. At the Experimental Station of Floriculture and Nursery Management in Friesdorf near Bonn.

2. At the Department of Fruit Culture of Technical University Munich.

3. At the Breeding Station of the Nursery Berlin-Baumschulenweg.

In Friesdorf, the breeders favoured the ornamental value during their selection works, resulted in the cultivar 4Friedorfer Orange'. At the other breeding stations, the aims covered mainly the utilization of the fruits. In Munich-Weihenstephan, Schimmelpfeng dealt with Hippophae selection since the beginning of the 1970s. The first objective was the search for suitable woody plants to recultivate waste land areas mainly with native fruit bearing trees and shrubs. At the beginning, the breeders used Hippophae rhamnoides ssp. rhamnoides for their selection works, later also used ssp. fluviatilis. As a result, two clones with high contents of ascorbic acid originated from the natural material. The first clones were sold to food industry, but they are no longer in cultivation (Schimmelpfeng, 1997). At the Breeding Station of the Nursery Berlin-Baumschulenweg, Albrecht and colleagues dealt with selection of clones and cultivars in several steps. Already during the 1960s, after systematic evaluations of natural populations, a generative propagated form of Hippophae named 'Auslese Ruegen' were selected and introduced, mainly used as wind resisters for maritime exposure. The second step was the selection of clones for fruit production. At that time, however, fruits from natural populations and earlier established plantations on waste lands had already been harvested for industrial made juice and soft drinks. But the requirements could not been fulfilled in that way. In addition, the fruit harvest in natural populations contained a conflicting potential with nature conservation law in Germany. Therefore, it was the first aim to select cultivars yielding a great amount of high qualitative fruits with high contents of fruit acid and vitamins. Forcing the selection work, all registered natural populations of Hippophae in East Germany were included. A great amount of individuals corresponding to the breeding targets were selected, cloned and evaluated in the nursery. Features of evaluation were the content of ascorbic acid, carotine and later also the content of tocopherol and oil. Further more, growth and yield characteristics with influence on harvesting technology were also evaluated. As a result, Albrecht and colleagues selected the female clone-type cultivars 'Leikora', 'Hergo', 'Frugana', 'Dorana' and 'Askola'. To guarantee a maximum of pollination and fertilization from a great amount of male individual plants, 4 male clones were selected and evaluated for their fertilization behaviour. Eventually, the male clones were named "Pollmix" with a supplementary clone number. After that successful selection work, many plantations were established with these cultivars in East Germany and other European countries.

With the installation of intensive cultivated seabuckthorn plantations, more and more new breeding targets arised from changed harvesting technologies and different uses of the fruits. One of the newer purposes in Germany was the production of oil from Hippophae fruits. Therefore a continuation of breeding was necessary.

Subsequently, Albrecht and colleagues propagated these clones by seeds to increase the variability again. The seeds originated from free pollination. Parts of the offsprings showed a large variability, a suitable opportunity to continue selection. Also the pollination of selected female individuals with selected male plants resulted in a large variability. From this several plants arised, showing important features like a very late ripening time and a stability in color of the fruits. At the same time, plant material of Hippophae rhamnoides ssp. mongolica originating from the Altai Mountains were included in the breeding progamme. Crossings of those with European populations brought up a few plants with a very early ripening time, with a high carotine content and some more suitable features. Clones arised from that material are being evaluation presently (Albrecht and Schuldt, 1997).

## CULTIVARS SELECTED IN GERMANY

The following list contains cultivars selected by Albrecht and colleagues in the Breeding Station of the Nursery Berlin-Baumschulenweg:

**Askola:** It has the early ripening and harvesting time in Berlin area from the end of August till the mid of September. The fruits are medium big-sized, oval shaped and orange colored. The fruits maintain their intensive color until winter time. It has very high fruit density. Fruit characteristic weight of 100 fruits is 29 g. Total fruit acid is 5.3%, ascorbic acid 260 mg%, carotine 12 mg%, tocopherol 28 mg% and oil 3.7%. The growth is strong and upright. Height without pruning is up to 5 m, strong main branches with some irregulary distributed side branches. Good regeneration after pruning can form 2 m long new shoots. It is medium spiny.'Askola' can be used for plantation culture. Under windy situations, there is a risk of branch breaking caused by the upright growth. During harvesting, the fruits loss by machines from short branches could occur due to the very compact fruit setting. 'Askola' was introduced in 1991 and is protected under plant licence in Germany.

**Dorana:** It also has early ripening and harvesting time in Berlin area from the end of August till the end of September. The fruits are medium to big-sized, oval to pear-shaped, intensive orange colored, stabile in color and have some pigments. Plants are rich in fruiting. Weight of 100 fruits is 25 g. Total fruit acid 4.9%, ascorbic acid 340 mg%, carotine 7 mg%, tocopherol 24 mg% and oil 3.4%. The plants are medium sized with an upright habit. Side branches are thin and distributed regularly. Weak regeneration after pruning back to older parts of the shrubs. It is medium spiny, less sucker formation. 'Dorana' can be used for plantation culture only under good soil conditions with sufficient water supply. Because of the tender growth 'Dorana' is suggested for using in small private gardens. Harvesting the berries is very easy, because of the long fruit petioles. 'Dorana' was introduced in 1990.

**Frugana:** It has very early ripening time and harvesting time in Berlin area between the mid and the end of August. The fruits are medium big-sized, oval shaped, bright orange colored and almost without pigments. From the mid of September the fruits loss their color. Mean value of weight of 100 fruits is 40 g. Total fruit acid is 3.5%, ascorbic acid 160-mg%, carotine-8 mg%, tocopherol-21 mg% and oil-4.1%. Strong growing, branches grow upright and are less branched. Height goes without pruning up to 4.0 m. It has good regeneration after pruning back. It is less spiny. 'Frugana' can be used for plantation culture. Under windy situations, there is a risk of branch breaking. Fruits can be harvested by machines. The berries stand along tall fruit branches and can be harvested easily, because of the long fruit petioles. The fruits are most suitable for making of juice and soft drinks because the juice is mild in taste. 'Frugana' was introduced in 1986.

**Hergo:** 'Hergo' has early ripening and harvesting time in Berlin area between the beginning and the mid of September. The fruits are medium-sized, oval to cylindrical-shaped, light orange colored and with only some pigments. Fruit petioles are short. The berries are less stable in color and turn to pale in October. The plants have heavy fruiting. Characteristics weight of 100 fruits is 37 g. Total content of fruit acid is 3.5%, ascorbic acid 150 mg%, carotine 5 mg%, tocopherol 16 mg% and oil 4.3 %. It is medium-sized shrub with a broad upright habit. It has good and regular branching with thin fruit branches. Its height without pruning is up to 4.0 m. It has good regeneration after pruning. It is medium spiny. 'Hergo' is a suitable plant for plantation culture and hedges in the countryside. Shrubs can be harvested by machines. Plants produce high amounts of fruits. But 'Hergo' is more sensitive to soil differences and water shortage compared to other cultivars. 'Hergo' was introduced in 1983.

**Leikora:** It has late ripening and harvesting time in Berlin area from the mid of September till the beginning of October. The fruits are big-sized, cylindrical to drop-shaped, dark orange colored, very stable in color with some pigments and with short petioles. They stand tight to the branches. The plants have rich fruiting. Mean values of weight of 100 fruits is 56 g, total content of fruit acid 3.4%, ascorbic acid 40 mg%, carotine 6 mg%, tocopherol 26 mg% and oil 4.9%.It has strong growing shrubs, medium-sized with a broad upright and compact habit, regulary branched with strong fruit branches. It has very good regeneration after pruning. It is less spiny 'Leikora' is most suitable for plantation culture. The shrubs are very resistant against wind exposures. After pruning, the shrubs need three years to obtain their full fruit yield again. The berries can be harvested by machines (shaking and rattling) only after a short-time freezing because of the high holding capacity of the fruits. Because of the color stability of the fruits 'Leikora' is most attractive as floristic material. Best cultivar for wind-exposed locations and for planting on slopes, as ornamental shrubs and for animal feeding. 'Leikora' was introduced in 1979 (Table 1).

**Table 1. Characteristics of fruits of German seabuckthorn cultivars**

| *Cultivar* | *Shape* | *Color* | *Wt. of 100 fruits (g)* | *Content of acid (%)* | *Oil (%)* | *Ascorbic acid (mg%)* |
|---|---|---|---|---|---|---|
| Askola | Oval | Orange | 29 | 5.3 | 3.7 | 260 |
| Dorana | Oval-pear-shaped | Dark orange | 25 | 4.9 | 3.4 | 340 |
| Frugana | Oval | Bright orange | 40 | 3.5 | 4.1 | 160 |
| Hergo | Oval-cylindrical | Light orange | 37 | 3.5 | 4.3 | 150 |
| Leikora | Cylindrical-dropshaped | Dark orange | 56 | 3.4 | 4.9 | 240 |

Note: Mean values in the territory of Berlin.

**Pollmix:** 'Pollmix' is the name for a group of male clones selected at the Breeding Station of the Nursery Berlin-Baumschulenweg. Their ability in pollination of the female cultivars 'Askola', 'Dorana', 'Frugana', 'Hergo' and 'Leikora' has been proved. Because of differences in the flowering period of female cultivars and because of weather influenced variations of the flowering period of the male clones at least two 'Pollmix' cultivars should be used for plantations with female cultivars.

**Pollmix 1:** It's juvenile growth is strong and upright. Shrubs are less branched with strong branches. Later broad upright in habit, almost without spines. Leaves are dark green. It has early flowering time.

**Pollmix 2:** Broad-up right growing and already well-branched as juvenile shrub. It has great amounts of thin branches and spines. Leaves are light silver green. It has early flowering time. Because of the spininess, 'Pollmix 2' is used rarely.

**Pollmix 3:** It has broad-upright growing with good side-branching. It is less spiny. It has late flowering time.

**Pollmix 4:** It is strong and upright growing with strong branches. It is less spiny. Its leaves are dark green and narrow linear.

## CULTURE OF THE CULTIVARS IN PLANTATIONS

In 1980, 'Leikora' was used as first seabuckthorn cultivar for fruit culture in plantations. Forcing the development of Hippophae plantation for fruit culture, a working group was formed under leadership of Koch in 1979. The working group combined scientists, breeders, specialists from nurseries, forestry, fruit culture farms and fruit manufacturing, trade managers and machine engineers. Therefore, the fruit culture of seabuckthorn cultivars was quickly developed in East Germany until 1990. At the same time, the cultivars of Hippophae were used for fruit culture at a plantation area of about 200 ha. Due to political and economical problems, a decrease in plantation area began in 1991. Only during the last few years, a slow increase in seabuckthorn plantation area could be gained.

The planting of the shrubs is carried out in rows with a distance of 4.0 m to 4.5 m to enable harvesting by machines. The distances within the rows between the plants are 1.0 m to 2.0 m, depending upon the cultivar. Later the plant rows will form hedges. The portion of the male 'Pollmix' clones should be about 8% to 10% to guarantee pollination. The cultivation in plantations is mainly carried out without the use of fertilizers, chemical pesticides and supplementary irrigation (biological cultivation methods). During the first years in some plantations, arised problems through damages, caused by game (Capreolus capreolus), especially in the young shrubs. Because of the high holding capacity of the fruits, the first harvesting methods include manual pruning of fruit branches. These fruit branches were cut into small pieces (5 to 8 cm) and defoliated. After washing the fruit branches, the berries were pressed producing seabuckthorn raw juice. For that purpose Grossmann developed a pressing machine already in the 1960s. These machines work with two moving rollers putting pressure on the berries and squeezing them. During the 1980s, the harvesting methods changed, because of economical aspects. At first, whole fruit branches (1.0 m to 1.3 m) are pruned. They are frozen for a short time (about - 35°C) and then the branches are rattled and the berries are removed from the branches by vibration.

At the same time, a harvesting machine was developed rattling the berries from small fruit branch pieces (about 1 cm) by vibration without cold treatment and without application of chemicals. The quality of the fruits is high, but there are differences in the applicability of this procedure between the cultivars. Pruning the plants, to harvest the fruit branches with berries in late summer time is also used as a regeneration method of the plants for their long-term use in the plantations. During that procedure, the shrubs are pruned back to 1.0 m to 1.5 m. Therefore the fruit harvest can be carried out only in a two year rotation, for the cultivar 'Leikora' only in a three year rotation. The fruits are mainly used to produce juice, soft drinks, jams and jellies and as 'bio-food' for health food shops. Recently the oil from the fruits and the seeds is used by the cosmetic industry in Germany.

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