# The Results of Harvesting the Berries of Common Seabuckthorn in Estonia

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## Abstract

Harvesting the berries is a key problem in cultivating common seabuckthorn in Estonia. We studied two methods of harvesting in the years 2004 to 2007.

In 2004 and 2005, we studied harvesting the yield by shaking method on 12 and 8 varieties of seabuckthorn, respectively. We found that labour productivity during harvesting depended more on the biological characteristics of cultivars than on the ripeness of the berries. The trials showed that the berry shaker HK-2 is suitable for harvesting berries from young shrubs (between 3 and 6 years old), with height not exceeding 2.5 metres. Cultivars better suited for mechanical harvesting include 'Botanicheskaya', 'Trofimovskaya', 'Otradnaya', and 'Botanicheskaya Lubitelskaya'. Labour productivity in harvesting the berries of these cultivars, given that the shaker is working continuously, is 23 to 43 kg per hour. The berry shaker leaves about 5 to 12% of the yield unharvested. The harvested mass contains 3 to 8% leaves and twigs. Around 6 to 23% of the berries are crushed during mechanical harvesting; the percentage depends on the ripeness of the berries as well as on cultivar.

In 2006 and 2007, the trial included the method of harvesting by cutting off fruitbearing branches, freezing them at -20 to -30°C, and separating the frozen berries. 10 varieties were studied. The frozen berries were easily - and from 99 to 100% of branches completely - separated from the branches. The speed of separating the berries did not vary significantly by cultivar. The yield included 73 to 85% of berries (the mean of all cultivars was 81%) and 19% of leaves and branches. An average of 3.2 kg of clean berries per minute was obtained. The average per hour was 192 kg. We found that to harvest the yield by cutting off fruit-bearing branches, shrubs with multiple trunks are preferred over shrubs with a single trunk.

Key words: seabuckthorn, harvesting, varieties.

## Introduction

In Estonia, the first trials with seabuckthorn (*Hippophaë rhamnoides* L.) were carried out in the middle of the 20-th century for the revegetation of alvars and sandy areas. In the 1980s, cultivars bred at the Altai Fruit Growing Institute and in the Moscow Botanical Gardens of the Moscow University were tested in Estonia (Jalakas et al., 2003). At present the varieties 'Avgustinka', 'Botanicheskaya', 'Botanicheskaya Lubitelskaya', 'Otradanya' and 'Trofimovskaya' are included in the list of cultivars recommended for growing in Estonia. Seabuckthorn is a popular crop in organic farming: in 2012 the area under organic plantation was 856 ha in Estonia. Seabuckthorn is widely used to add value to different food products such as juices, jams, milk products, and snacks.

As the ripening berries become soft, harvesting is a key problem in cultivating sea buckthorn. Manual harvesting requires approximately 1500 h of human labour per every hectare of orchard (Gaetke et al, 1991). Attempts at harvesting seabuckthorn berries mechanically have typically revealed the problems of fruit damage and low efficiency. Mechanical fruit harvesters can be classified as either direct harvesters or indirect harvesters (Olander, 1995). The concepts that have been tried include tree shakers, vacuum suction units, quick freezing units, and "whole branch harvesters" (Mann et al, 2001).

The first branch shaker prototype in Estonia was built by Hando Kruuv. The device was tested in Southern Estonia in the plantations of Rohu Experimental Centre in 2000 and 2001 and improved upon in the following years. The Estonian University of Life Sciences performed a study to ascertain the optimal harvesting time of different seabuckthorn cultivars and cultivars best suited for harvesting with the shaker HK-2 from 2004 to 2006.

**Materials and Methods**

The branch shaker HK-2 consists of a rubber-lined clamp that is used to hold on to the seabuckthorn branch, a crankshaft that moves the clamp back and forth, and an actuator of the brush cutter STIHL FS 80. The crankshaft moves the clamp back and forth at amplitude of 25.5 mm. The branch shaker kit includes a funnel-shaped plastic mesh berry collector that is placed under the tree. The berries are then funneled from the collector into crates.

Trials with the seabuckthorn branch shaker HK-2 were carried out at Polli Institute of Horticultural Studies of the Estonian University of Life Sciences, Rohu Experimental Centre, and seabuckthorn orchards of Berry Farming OU in 2004 and 2005. The trial studied the suitability of the berries of 13 seabuckthorn cultivars of Russian origin for harvesting with a branch shaker, as well as the productivity of harvest and quality of yield. In 2004, there was a preliminary trial with 10 cultivars in one repetition to ascertain the most promising cultivars for harvesting by shaking: 'Botanicheskaya', 'Botanicheskaya Lubitelskaya', 'Otradanya', 'Luchistaya', 'Trofimovskaya', 'Podarok Sadu', 'Gibrid Perchika', 'Moskovkaya', 'Kaliningradskaya', 'Finskaya', and 'Prozrachnaya'. The berries on 5-year-old trees were harvested in three stages of ripeness: at an early stage of picking ripeness (August 18-19), at agricultural ripeness (Aug 27-30), and at the start of over-ripeness (Sep 8-9). In 2005, five cultivars of these, all widely grown in Estonia and deemed best suited for further trials of harvesting by shaking were selected for a trial in three repetitions: 'Botanicheskaya', 'Botanicheskaya Lubitelskaya', 'Otradanya', 'Podarok Sadu', and 'Gibrid Perchika'; in addition to these, 'Trofimovskaya', 'Vorobyovskaya', and 'Avgustinka' with 6 to 8-year-old trees. The berries were picked in agricultural ripeness phase. The productivity of the harvest was determined based on the total yield and the time used to harvest it. The leaves and twigs were separated from the yield and the proportion of debris determined. The amount of berries left on the tree after the harvest was determined visually (as %) in the preliminary trial and by the yield obtained by manual post-harvest berry picking in the main trial. The reliability of the results was tested in the main trial by one-tailed dispersion analysis at 95% probability.

Harvesting seabuckthorn berries by the method of cutting the berry-bearing branches was studied in 2006. Branches with berries were cut off at 1.5 m from the ground. Smaller branches with berries were cut into pieces of 25 to 30 cm; longer shoots with leaves were removed. Branches with berries were placed in crates holding 10 kg and frozen for 14 hours at ca -36° C and stored at -20° C. Berries were separated from frozen branches by vibration method. The total yield was weighed first, and then clean berries and branches weighed separately. Separated leaves were weighed as a total for the batch. The time of separating and cleaning the berries was used to calculate productivity.

To evaluate the morphological differences of the berries of different seabuckthorn cultivars, the average mass of berries was calculated based on 100 berries. Damaged berries were separated and counted. The length of stems and crosswise and lengthwise diameter were measured in batches of 10 berries.

**Results and Discussion**

The preliminary trial in 2004 demonstrated that the productivity and quality of harvesting seabuckthorn berries with branch shaker HK-2 is significantly related to the cultivar and the stage of

ripeness (Table 1). At an early stage of picking ripeness when 10 to 15% of berries were still greenish, the berries of the cultivars 'Podarok Sadu', 'Moskovskaya', 'Prozrachnaya', 'Finskaya' and 'Kaliningradskaya' did not separate by shaking. Productivity was low with other cultivars (14 to 29 kg/h). Productivity was up to two times as large (32 to 48 kg/h) in harvesting the berries of these cultivars at the stage of agricultural ripeness. From 5 to 20% of the yield was left unharvested. Productivity was low (14 to 21 kg/h) in harvesting the cultivars 'Kaliningradskaya', 'Finskaya' and 'Prozrachnaya'; from 20 to 50% of the yield was left unharvested. The berries of the cultivars 'Podarok Sadu' and 'Moskovskaya' did not separate by shaking even at the stage of agricultural ripeness. The berries of the cultivars studied were most easily separated by shaking at an early stage of over-ripeness but, in the case of the cultivars with berries that did not separate easily, from 20 to 50% of the yield was left unharvested by shaking. Debris content of the yield in harvesting by shaking was 1.8 to 8.9%, and there was no clear relationship between cultivars and the stage of ripeness of the berries.

Table 1. The results of the preliminary trial of harvesting seabuckthorn berries with branch shaker HK-2 (2004).

| ***Cultivar*** | ***Productivity, kg/h*** | | | ***Debris content, %*** | | | ***Unharvested berries, %*** | | |
|---|---|---|---|---|---|---|---|---|---|
| | ***1*** | ***2*** | ***3*** | ***1*** | ***2*** | ***3*** | ***1*** | ***2*** | ***3*** |
| Botanicheskaya Lubitelskaya | 24 | 32 | 48 | 1.9 | 4.3 | 6.8 | 15 | 10 | 10 |
| Otradnaya | 23 | 49 | 71 | 3.3 | 5.1 | 3.9 | 15 | 10 | 10 |
| Podarok Sadu | x | x | 49 | x | x | 7.7 | x | x | 50 |
| Gibrid Perchika | 14 | 48 | 96 | 7.0 | 4.4 | 1.8 | 20 | 10 | 5 |
| Luchistaya | 29 | 48 | 80 | 5.9 | 1.9 | 4.3 | 10 | 5 | 3 |
| Botanicheskaya | 24 | 46 | 65 | 1.6 | 5.8 | 4.1 | 25 | 20 | 25 |
| Moskovskaya | x | x | 27 | x | x | 2.5 | x | x | 50 |
| Kaliningradskaya | x | 17 | 44 | x | 8.6 | 8.9 | x | 50 | 20 |
| Finskaya | x | 14 | 22 | x | 2.8 | 5.0 | x | 50 | 20 |
| Prozrachnaya | x | 21 | 49 | x | 5.4 | 7.8 | x | 20 | 50 |

*Note: 1 - harvesting at an early stage of picking ripeness (Aug 18-19), 2 - harvesting at agricultural ripeness (Aug 27-30); 3 - harvesting at an early stage of over-ripeness (Sep 8-9); x - berries could not be separated*

Table 2. Harvesting sea buckthorn berries with branch shaker HK-2

| ***Cultivar*** | ***Productivity, kg/ha*** | ***Unharvested yield, %*** | ***Debris content %*** | ***Crushed berries, %*** |
|---|---|---|---|---|
| Botanicheskaya | 43.3 | 5.1 | 7.7 | 15 |
| Avgustinka | 21.8 | 31.3 | 9.6 | 14 |
| Trofimovskaya | 34.1 | 11.8 | 5.4 | 12 |
| Vorobyovskaya | 24.1 | 13.5 | 7.1 | 10 |
| Botanicheskaya Lybitelskaya | 39.2 | 5.2 | 3.4 | 23 |
| Otradnaya | 37.5 | 8.0 | 3.6 | 19 |
| Podarok Sadu | 22.1 | 28.0 | 3.1 | 9 |

| | | | | |
|---|---|---|---|---|
| Gibrid Perchika | 25.7 | 30.7 | 1.6 | 12 |
| LSD 0.05 | 16.3 | 10.3 | 3.1 | |

The results of harvesting at the stage of agricultural ripeness of the berries performed in 2005 (Table 2) revealed that productivity was the greatest with the cultivars 'Botanicheskaya', 'Botanicheskaya Lubitelskaya' and 'Otradnaya' (37.5 to 43.3 kg/h), and over 90% of the berries were separated by shaking. Productivity was somewhat lower but still satisfactory (24.1 to 34.1 kg/h) in harvesting the trees of 'Trofimovskaya' and 'Vorobyovskaya' that were three years older than the trees of the former group of cultivars and from 11.8 to 13.5% of the yield was left unharvested. Productivity was the lowest (21.8 to 25.7 kg/h) for harvesting the berries of the cultivars 'Avgustinka', 'Podarok Sadu' and 'Gibrid Perchika'. From 28.0 to 31.3% of the yield was left unharvested by shaking. The yield from the cultivars 'Avgustinka', 'Trofimovskaya' and 'Vorobyovskaya' contained more leaves and twigs (5.4 to 9.6%); the debris content of the other cultivars was below 5%. From 9 to 23% of the berries were crushed in the process; the share of crushed berries was the largest for the cultivar 'Botanicheskaya Lubitelskaya', the berries of which have a thin and weak skin. The berries of the cultivars 'Podarok Sadu' and 'Otradnaya' had the toughest skin (Table 3). The size of the berries of 'Finskaya' and 'Kaliningraskaya' was the smallest (0.4 g); the berries of 'Podarok Sadu', 'Moskovskaya' and 'Botanicheskaya' were a bit larger (0.5 g). The berries of 'Gibrid Perchika' were the largest (0.7 g). It may be concluded that as a rule the berries of the cultivars with smaller berries are difficult to separate by shaking, although there may be exceptions to this rule ('Botanicheskaya'). However, the ease with which the berries are separated does not depend only on the size of the berries: the large berries of 'Gibrid Perchika' were also difficult to separate. The length of the stem of the berries did not have a significant effect on the results of the harvest: the berries of the cultivar with the longest stem, 'Prozrachnaya' (4.4 mm), and the berries with a cultivar with a significantly shorter stem, 'Avgustinka' (2.5 mm), were equally difficult to separate.

Table 3. Morphological characteristics of seabuckthorn berries 2004 - 2006.

| ***Cultivar*** | ***Average berry mass, g*** | ***Diameter of berries, mm*** | | ***Length of stem, mm*** | ***Strength of berry skin, N*** |
|---|---|---|---|---|---|
| | | ***lengthwise*** | ***crosswise*** | | |
| Botanicheskaya | 0.5 | 10.9±0.2 | 9.4±0.1 | 3.3±3.2 | - |
| Botanicheskaya Lubitelskaya | 0.6 | 13.4±0.9 | 9.5±0.1 | 2.7±0.1 | 199±31 |
| Otradnaya | 0.6 | 12.1±0.2 | 9.2±0.1 | 2.4±0.2 | 297±49 |
| Moskovskaya | 0.5 | 10.6±0.2 | 8.8±0.1 | 3.4±0.2 | - |
| Prozrachnaya | 0.6 | 12.0±0.1 | 9.7±0.1 | 4.4±0.2 | - |
| Gibrid Perchika | 0.7 | 12.1±0.2 | 9.1±0.1 | 3.2±0.1 | - |
| Avgustinka | 0.6 | 12.8±0.2 | 9.5±0.1 | 2.5±0.1 | 203±32 |
| Trofimovskaya | 0.6 | 13.5±0.2 | 9.6±0.1 | 2.7±0.1 | 245±40 |
| Vorobyovskaya | 0.6 | 12.8±0.3 | 9.0±0.2 | 2.5±0.1 | 210±34 |
| Luchistaya | 0.6 | 10.7±0.2 | 10.0±0.1 | 3.1±0.1 | - |
| Podarok sadu | 0.5 | 11.0±0.3 | 8.4±0.2 | 2.7±0.1 | 304±51 |
| Finskaya | 0.4 | 10.8±0.2 | 7.8±0.1 | 3.6±0.1 | - |
| Kaliningradskaya | 0.4 | 9.8±0.1 | 7.9±0.1 | 3.1±0.1 | - |

The trial demonstrated that the results of harvesting seabuckthorn berries by shaking depend on biological characteristics of cultivars, mainly on how tightly the berries are attached to the branches. A German study found that this differed widely by cultivar (1.3 to 5 N) and remained constant during the whole harvesting period (Achrafi et al, 1990). Time of harvest, shaker's frequency and amplitude of motion are important factors in harvesting with a shaker. Satisfactory results were achieved with a shaker at the frequency of 25 Hz and amplitude 32 mm (Mann et al, 2001). With smaller amplitude, the frequency has to be up to 30 Hz to separate the berries (Gaetke et al, 1991). The correct ratio of frequency and amplitude provides the impetus necessary for separating the berries.

The cultivars with shorter and more rigid branches are better suited for harvesting with a shaker. In the case of cultivars with long pliable branches, a part of the shaker's energy is lost (Olander, 1995). The harvester HK-2 used in our trial is intended for shaking branches. The clamp clasps onto a branch with <3 cm thickness without damaging the bark of the branch. During shaking, most berries fall from the part that the clamp is attached to. Therefore, the harvester should move from the base of the branch towards the tip to ensure even separation of berries. Branches with a diameter <0.5 cm are difficult to clasp on to and break easily.

The berries harvested with a branch shaker are collected into two crates placed under a plastic mesh collector on wheels that is positioned around the tree trunk. When shaking taller trees with a wider canopy, up to 5% of the yield falls over the edge of the collector. Another 5% of the yield is lost when the berries are funnelled into the crates. To minimize these losses, the trees should have a single low trunk so that the collector can be tightly fitted. It is most efficient to use two workers and two collectors per shaker. One of the workers can operate the shaker while the other fits the spare collector around the next tree, funnels the berries from the collector to the crates and stows the crates for transport. Productivity per worker when harvesting cultivars that are suited for shaking is between 100 and 170 kg per day, i.e., 10 to 17 times higher than with picking the berries manually. Yield loss with branch shaker HK-2 is about 20%, 10% of which is left on the trees and 10% is lost during harvesting. As the harvested berries are wet due to crushed berries and contain 3 to 8% of leaves and twigs, the crop is only suited for juice and related products. Harvesting the berries with the branch shaker did not cause significant damage to seabuckthorn trees.

Harvesting seabuckthorn berries by cutting off fruit-bearing branches and separating them after freezing yielded 73 to 85% of clean berries (Table 4). The average for all cultivars was 81% of berries and 19% of twigs and leaves. The weight of twigs in the harvested yield was 8.5% and did not depend on the cultivar. The amount of leaves, underdeveloped berries and other debris was somewhat greater (10.5%). With vibration, the berries of all cultivars were easily and completely separated from the branches. The speed of breaking the frozen stems and separating berries did not differ from one cultivar to another. As an average of all cultivars, one minute of work time yielded an average of 3.1 kg of clean berries, one hour up to 192 kg and an 8-hour shift approximately 1.5 tons.

Table 4. Productivity of separating seabuckthorn berries from frozen branches by vibration method.

| ***Cultivar*** | ***Amount processed (kg)*** | ***Processing time (min)*** | ***Clean berries*** | | ***Productivity*** | | ***Debris*** | |
|---|---|---|---|---|---|---|---|---|
| | | | ***kg*** | ***%*** | ***kg/min*** | ***kg/h*** | ***branches*** | ***leaves*** |
| Botanicheskaya Lubitelskaya | 9.4 | 2.37 | 7.8 | 83 | 3.3 | 198 | 0.6 | |
| Otradnaya | 10.7 | 2.44 | 7.8 | 73 | 3.2 | 192 | 0.9 | |
| Podarok Sadu | 9.1 | 2.18 | 7.1 | 78 | 3.3 | 198 | 0.9 | |
| Gibrid Perchika | 11.3 | 3.00 | 9.2 | 81 | 3.1 | 186 | 0.9 | |
| Luchistaya | 11.2 | 3.05 | 9.4 | 84 | 3.0 | 180 | 0.9 | |
| Botanicheskaya | 13.4 | 3.00 | 10.0 | 75 | 3.3 | 198 | 0.8 | |

| | | | | | | | | |
|---|---|---|---|---|---|---|---|---|
| Moskovskaya | 12.3 | 3.15 | 10.2 | 83 | 3.2 | 192 | 0.8 | |
| Prozrachnaya | 11.7 | 3.12 | 10.0 | 85 | 3.2 | 192 | 0.9 | |
| Trofimovskaya | 10.0 | 2.20 | 8.3 | 83 | 3.8 | 228 | 1.3 | |
| Vorobyovskaya | 9.1 | 2.00 | 7.4 | 81 | 3.7 | 222 | 1.2 | |
| Avgustinka | 10.1 | 3.04 | 8.2 | 81 | 3.7 | 222 | 0.9 | |
| Total | 118.3 | 29.55 | 95.4 | 81 | 3.2 | 192 | 10.1 | 12.8 |

The method of cutting off berry-bearing branches and separating the berries after freezing results in a significant decrease in the overall yield of an orchard. The berries can be harvested only every other year. Based on visual evaluation, about 15 to 20% of the yield remains unharvested even in the year of a harvest. However, the high quality of the yield makes this method attractive.

## Conclusions

The Estonian University of Life Sciences studied, firstly, the method of harvesting seabuckthorn berries with a branch shaker HK-2 and, secondly, the method of cutting off berry-bearing branches and separating the berries after freezing the branches. The trials showed that labour productivity and the quality of the yield depended on the time of harvesting and the biological characteristics of cultivars. During the early stage of picking ripeness (when 10 to 15% of the berries were still green) the berries were difficult to separate; during agricultural ripeness the berries were more easily separated, and during the early stage of over-ripeness the berries were most easily separated. The cultivars of ‘Botanicheskaya’, ‘Trofimovskaya’, ‘Otradnaya’ and ‘Botanicheskaya Lubitelskaya’ are well suited for harvesting by branch shaking. The biological characteristics of cultivars had no effect on the quality of the yield when harvesting the berries by cutting off the fruit-bearing branches and separating the berries by vibration after freezing the branches. However, this harvesting method may have a negative effect on the health of the trees and the longevity of the plantation.

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