POLISH JOURNAL OF NATURAL SCIENCES
Abbrev.: Pol. J. Natur. Sc., Vol 30(4): 417–430, Y. 2015

COMMON SEA BUCKTHORN (*HIPPOPHAE RHAMNOIDES* L.) AS AN ALTERNATIVE ORCHARD PLANT

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K e y w o r d s: sea-buckthorn, varieties, crop productivity, use value.

A b s t r a c t

Due to the wealth of nutrients contained in the sea buckthorn (*Hippophae rhamnoides* L.) fruit, it is a raw material attracting increasing interest from the food and pharmaceutical industries. Sea buckthorn is also a plant with low soil requirements while being drought-resistant. Therefore, it may offer an alternative to farmers who have either soils poor in minerals or degraded land in need of soil values being restored to it. Sea-buckthorn, due to its ability to fix nitrogen, excellently fertilises poor and degraded soils.

ROKITNIK ZWYCZAJNY (*HIPPOPHAE RHAMNOIDES* L.) JAKO ALTERNATYWNA ROŚLINA SADOWNICZA

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S ł o w a k l u c z o w e: rokitnik, odmiany, plonowanie, wartość użytkowa.

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Abstrakt

Bogactwo składników odżywczych i zdrowych owoców rokitnika (*Hippophae rhamnoides* L.) sprawia, że jest owocem cieszącym się coraz większym zainteresowaniem w przemyśle spożywczym oraz farmaceutycznym. Rokitnik to również roślina o niewielkich wymaganiach glebowych a jednocześnie odporna na suszę. Tym samym może stanowić alternatywę dla rolników posiadających gleby ubogie w składniki mineralne bądź też grunty zdegradowane, które wymagają przywrócenia im wartości glebowych. Rokitnik dzięki swym zdolnościom do wiązania azotu doskonale użyźnia ubogie i zdegradowane gleby.

Common sea buckthorn (*Hippophae rhamnoides* L.), also referred to as the 'Siberian pineapple', is a valuable medicinal plant. First notes concerning the therapeutic properties of the sea buckthorn were written in 7th century C.E. in Tibetan medical books. The origin of the plant name comes from ancient times when Greeks fed horses with sea buckthorn in order for their hair to be shiny, and thus the common name has been established (*hipp* – horse, *phaos* – shiny). In ancient times, all structural parts of the shrub were used for therapeutic purposes: fruits, leaves, bark, and even the roots.

Sea buckthorn fruit is among the most nutritious and rich in vitamins, polyphenols, minerals, and organic acids. The plant, similar to olives or avocado, contains fats in the pulp of the fruit. This fat is distinct from other fats because it is considered to have significant therapeutic properties. The oil is used for the treatment of frostbite, poorly healing wounds, or eczemas. Sea buckthorn oil was used for the treatment of radiation burns caused by the Chernobyl explosion.

The therapeutic properties of sea buckthorn fruit have contributed to an increasing interest in the production and processing of these fruits over the recent years.

Sea-buckthorn, in its natural state, occurs as a wild plant in Central Asia, China, Tibet, Mongolia, the Caucasus, Turkey and Russia, and grows in the areas of Siberia, Central Europe, and the Baltic Sea and North Sea coasts. Its range of occurrence reaches as far as Great Britain (Figure 1) (LI and BEVERIDGE 2003, SZAŁKIEWICZ and ZADERNOWSKI 2006, BATOOL 2011). Due to the variety of climatic conditions, various species and varieties of this plant grow in particular areas of Eurasia (Figure 1). So far, approx. 150 species of sea buckthorn have been identified within Eurasia (Table 1), differing not only in the habitat of the shrub but also in the appearance and use-value of the fruit.

Table 1

Species of sea buckthorn – Part 1

Lp.	Cultivar	Yield kg·skrub^{-1}	Lp.	Cultivar	Yield kg·skrub^{-1}
1	Awgustinka	12,5–20,5	45	Diujmowoczkaja	7,9
2	Alej	–	46	Ełizaweta	7,1
3	Altajechka	7,6	47	Żołtaja rannaja	30
4	Altajskaja	8	48	Żiwko	13–20
5	Ananasnaja	6,7	49	Zariewo	11,6–14,5
6	Atsula	14	50	Zarnica	7–8,5
7	Ayula	15,5	51	Zarja Dabat	6,7–9,0
+–					
8	Ayaganga	7,5–10,2	52	Zarja Meszczery	6,0–7,0
9	Bazeliskaja	7,0	53	Zołatoja kosa	5,8–12
10	Bajkal	7,8	54	Załatistaja Sibiri	6,8–14,0
11	Bajkaliskij rubin	8,5	55	Zołotoj kackad	10
12	Bajan Gol	8,5–12,2	56	Zołotoj kliuczik	4,8
13	Bijczanka	6,8	57	Zyrjanka	–
14	Bogatyrskaj	9,6	58	Iwuszka	8
15	Botaniczeskaja	20,5	59	Inja	8–12
16	Botaniczeskaja aromatnaja	9,8–15	60	Kapriz	–
17	Botaniczeskaja luczistaja	10	61	Karamelika	7
18	Botaniczeskaja liubitelickaja	7–15	62	Karotinnaja	6–8
19	Businka	9	63	Katunskaja –24	6–10
20	Batutinskaja	10	64	Kenigsbergskaja	–
21	Welikan	9	65	Kostior	18
22	WIL-5(15–1–36)	3,0–7,0	66	Krasawica Niecziernoziemja	8,5
23	WIL-7	4,0	67	Krasnopłodnaja (17397-20)	20
24	WIL-8	2,8–4,1	68	Krasnyj karlik	5
25	WIL-9	5	69	Krasnyj fakieł	8–9
26	WIL P-2	10	70	Kudrina	14,3
27	WIL P-3	11	71	Lilła kaług inna	8–9
28	WIL P-4	11	72	Lisiczka	8–13
29	Witaminnaja(B29)	4,3–13	73	Lomonocowskaja	14
30	Wladimipka	3,8–6,5	74	Luczezapnaja	8–9
31	Wopobiockaja	11–18	75	Ljubimaja	8–13
32	Wostocznaja	–	76	Ljudmila	–
33	Galerit	10	77	Majutka	3
34	Gibrid Perczika	11–23	78	Marinka	4–5
35	Gomełiskaja	25	79	Marija	10–12
36	Guś-Hructalinaja	7,7	80	Masłicznaja	11
37	Dar-Kazakowu	17,5	81	Mendieleewskaja	15
38	Dar MGU	20	82	Meszczerskaja krupnopłodnaja	7
39	Desert maslicznyj	6,5	83	Minusa	12–20
40	Desertnaja	7,3	84	Moria czka	11
41	Donczanka	8	85	Mockwiczka	14–20
42	Drużina	9	86	Moskowskaja ananasnaja	14–17
43	Dubowczanka	12–15	87	Moskowskaja krasawica	30
44	Dyet	12–18	88	Moskowskaja prozracznaja	–

Source: (SKALIJ 2007)

Table 1

Species of sea buckthorn – Part 2

Lp.	Cultivar	Yield kg·skrub^{-1}	Lp.	Cultivar	Yield kg·skrub^{-1}
89	Niżiegorodskaja suwienir	14,2	125	Sajana	10
90	Nariadnaja	12–15	126	Sewernyj diesiert	5,3
91	Niwieliena	35	127	Sejanec Welikana	5,7
92	Niżiegorodskaja cladkaja	8–10	128	Sibirskaja	9–11
93	Nadieżda	5–8	129	Sibirskij rumianec	10
94	Nowinskaja	10	130	Slawnaja	8–11,8
95	Nowosti Ałtaja	10	131	Solnecznaja	7–8
96	Obilynaja	20	132	Solnyszko	9–11
97	Ognistaja	–	133	Startowaja	5,9
98	Omska ja–27	6,5	134	Stoliczna ja	14,5
99	Oranżewaja	22	135	Studenczeskaja	20
100	Otradnaja	94–16,6	136	Sjurnpiz Baltiki	9,7
111	Poliwitaminnaja	7,7	137	Talickaja	12
112	Populiarnaja	7–104	138	Timipiazewskaja krasawica	5–77
113	Priewoshodnaja	7,1	139	Trofimowskaja	–
114	Prieliesti	7,2	140	Ułała	10
115	Prima Dona	–	141	Uniwiersitetskaja	12
116	Primorczanka	–	142	Urożajnaja	–
117	Priokskaja	9–18	143	Fantastika	–
118	Rannaja stołowaja	–	144	Finskaja	19
119	Rossijanka	20	145	Czeczek	10–25
120	Ruet	8	146	Czujskaja	23
121	Ryżik	1–18	147	Czulyszmanka	10–17
122	Riabinka	15,7–25,2	148	Szczerbinka	10
123	Riabinowaja	5	149	Jantarnaja	9,7
124	Samorodok	5–12	150	Jantarnoje ożerelie	11,2

Source: (SKALIJ 2007)

Sea buckthorn can be grown almost everywhere: in parks, gardens, on slopes, hillsides, on riverbanks, and on littoral dunes. When growing under the diversified climatic conditions of Eurasia, it is resistant to extreme temperatures from -43°C to 40°C. In addition, sea buckthorn is a plant with minimum soil quality requirements and, at the same time, it is drought-resistant (LI and BEVERIDGE 2003, KAWECKI et al. 2007). Therefore, it may offer an alternative to farmers who have either soils poor in minerals or degraded land in need of soil texture being restored to it. Sea-buckthorn, due to its ability to fix nitrogen, excellently fertilises poor and degraded soils. In addition, the plant exhibits natural resistance to pests, therefore the use of pesticides harmful to the environment may be reduced to a great extent. This means that sea buckthorn shrubs are suitable as a crops because they are both environmentally friendly and suitable for land reclamation (GIEJBOWICZ and WOŁEK 2008).

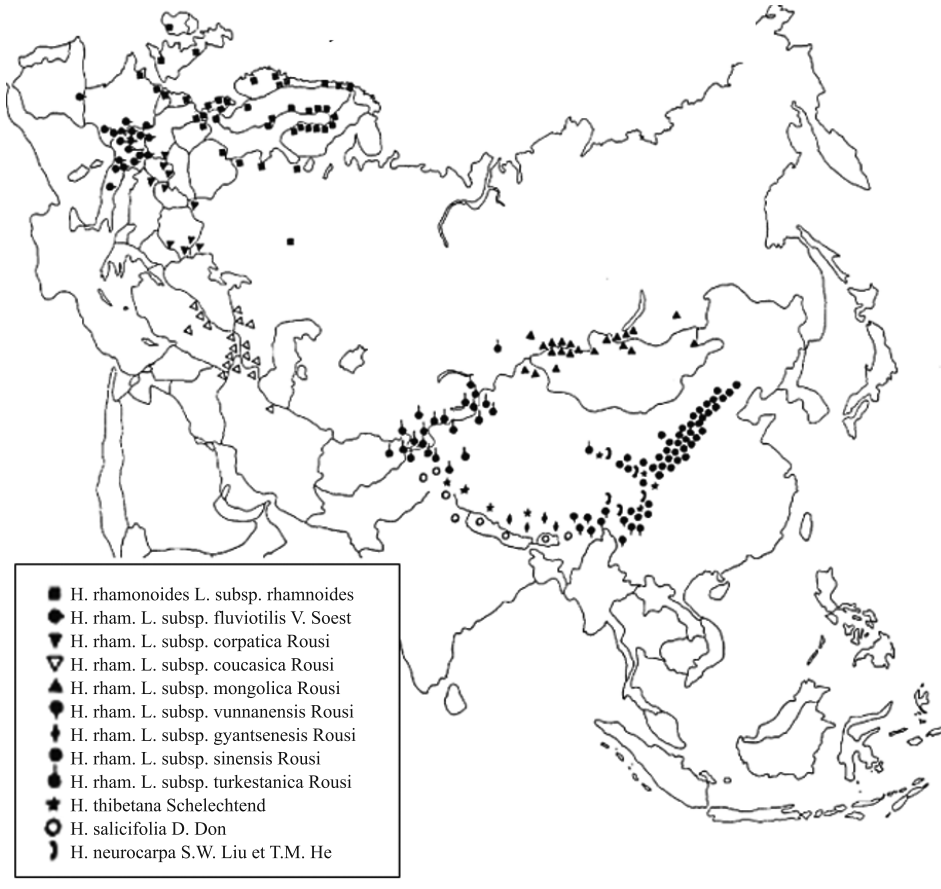

Fig.1. The presence of sea buckthorn (Hippophae rhamnoides) in Eurasia
Source: Li and Beveridge (2003)

As mentioned earlier, sea buckthorn is a wild plant. In Poland, it is only found in its natural state on the Baltic coast, where it grows on littoral dunes. In 1983, it was subjected to strict species protection, and currently, pursuant to Article 48 of the Act of 16 April 2004 on nature protection (Journal of Laws of 2013, item 627, as amended), it is under partial protection. Since the 1950s, two institutes have been involved in the improvement and adaptation of the plant to the orchard and commodity cultivation: the Russian Institute in Moscow, and the Belarusian Fruit-Farming Institute in Samokhvalovichi near Minsk. After years of research, several dozen improvedsea buckthorn varieties have been created, which primarily differ in crop productivity, harvest ease (due to increased pedicel length), and the quality of fruit. Improvements in fruits, include their size, colour, texture, structural and morphological charac-

teristics, and, primarily, the chemical composition have been considered (SHALKIEVICH et al. 2009).

This focus on cultivation research into the plant arises from the fact that the main asset of the sea buckthorn is its fruit with its high nutritional and health-promoting properties. Also, the oil derived from sea buckthorn fruit and seeds is an extremely valuable resource which is in demand from the pharmacological and cosmetics industries. The industrial use of sea buckthorn fruit was initiated in Russia in 1940 when scientists discovered and identified the wealth of biologically active substances found in the fruit, leaves, and bark. The first Russian plant manufacturing sea-buckthorn-based products is situated in Bisk (Altai Krai). These products have been used in both the diets of Russian astronauts and as a cream protecting against cosmic radiation (DELABAYS and SLACANIN 1995, XU et al. 2001). Chinese experiences in the industrial use of sea buckthorn fruit are more recent, even though they have been traditionally used for centuries (LU 1992). The research and establishment of commodity plantations in China were initiated in 1980. Since 1982, sea buckthorn has been planted on 300.000 ha. In addition, it has been found that approximately 150 plants process the fruits of the plant, and manufacture over 200 articles.

In Poland, there are very good climatic and soil conditions that provide Polish farmers the opportunity to grow sea buckthorn as an alternative crop (GIEJBOWICZ and WOŁEK 2008). At the same time, sea buckthorn crops may contribute to fulfilling numerous needs of specific sectors of the food, pharmaceutical, and cosmetics industries.

In Poland, research work was carried out in the years 2011–2014 as part of the programme NN312170939 financed by the Ministry of Science and Higher Education in Warsaw, and then by the National Science Centre (*NCN*) in Cracow. As part of the project, waste-free technology for processing the fruit of sea buckthorn (*Hippophae rhamnoides L.*) was developed, and the bioactive properties of the resulting products were assessed. The project was implemented under the supervision of Prof. Ryszard Zadernowski, at the University of Warmia and Mazury in Olsztyn, at the Department of Processing and Chemistry of Plant Materials. As mentioned earlier, sea-buckthorn is cultivated on a commercial scale primarily in Eurasia, e.g., in Russia, China, Finland, Germany, Lithuania, the Czech Republic, Slovakia, and Estonia. In Poland, small sea buckthorn plantings were established mainly in the Suwałki Region and near Łomża (Photo 1). These plantations have shown that such plantings may be also attempted in other parts of the country. In the 20th century, an attempt was made to cultivate this plant in North America, in the eastern, central and western provinces of Canada (LI and BEVERIDGE 2003). In Canada, sea buckthorn is cultivated in the following provinces: British Columbia,

Photo. 1. The experimental plantation of sea buckthorn (2ha) Amaranth Companies in Lomza and its owner John Hołownia
Source: B. PIŁAT

Alberta, Saskatchewan, Manitoba, Quebec, and Newfoundland (HARRISON and BEVERIDGE 2002). Currently, Canada is among the global leaders in the cultivation of sea-buckthorn. In the province of Quebec, a pilot area for the cultivation and processing of this plant has been designated in the town of Matane. In this region, approx 36 manufacturers and approx. 78.000 plants are found. The variety most often used for plantings, and recommended by the Ministry of Agriculture, Fisheries and Food of Quebec, is 'Indian summer' (MAPAQ, 2002). Under the climatic conditions of Canada, female plants start producing fruit in the 4th to 6th year after planting (LI and BEVERIDGE 2003), and in the first few years, they can yield a crop of fruit at a level of 0.75-1.5 t per ha (LU 1992). SCHROEDER and YAO (1995) recorded production of fruit at a level of 4–5 t per ha in Saskatchewan, while in British Columbia, cases of crop productivity at a level of 20–25 t·ha^{-1} were noted (LI and BEVERIDGE 2003). Research into the acclimatisation and use of sea buckthorn is carried out by the Pacific Agri-Food Research Centre in Summerland, British Columbia. The aim of the research that has been carried out for several years is to develop manufacturing technologies for commodity sea buckthorn varieties that would be suitable for cultivation in the climate prevailing in Canada, and to develop technologies of manufacture of valuable products (with an added value) in North America (LI and BEVERIDGE 2003). The research and

production issues being addressed by the Centre include, *inter alia*, the timeliness of ripening and the associated difficulties with harvest. Difficulties with harvest, as regards the traditional varieties, result from the short length of the berry pedicel, and the firm attachment of the fruits to branches. In addition, cultivation work is carried out with an aim to decrease the size and spread of trees, the development of a method and system for cutting shoots, and control of diseases, insects and pests, and the development of a technique of combine harvesting.

It is known that the basis for the development of food, pharmaceutical and cosmetic products is the profound knowledge of the chemical composition of raw materials. In the Polish market, there are products manufactured mostly based on imported sea buckthorn oil. Only in recent years has the manufacture of sea buckthorn oil from domestic fruit been initiated.

Sea buckthorn as an unconventional orchard plant

Common sea buckthorn *(Hippophae rhamnoides* L.) is a plant that grows and develops in a form of a shrub or a tree, whose height exceeds 3, and sometimes even 7 metres, while according to the literature, certain varieties may grow as tall as 20 metres. The plant has narrow and lanceolate leaves with a silvery bloom on the upper surface (ROUSSEAU 2002), and a green lower surface. Sea-buckthorn is a dioecious, anemophilous plant of the oleaster family (*Elaegnaceae*) (GIEJBOWICZ and WOŁEK 2008). Sea buckthorn flowers are produced in the early spring. They are inconspicuous, and yellowish in colour. Since the sea buckthorn is a dioecious plant, it has unisexual flowers, which means that female flowers grow on certain shrubs on which the fruits are set, while on different shrubs, male flowers grow (Figure 2) and their task is to produce pollen for the fertilisation of female flowers. The fruits are classified as non-climacteric. Depending on the variety, ripe fruits are oval-shaped and most often yellow, orange or red in colour. The weight of the fruit is usually within the range of 4–60 g 100^{-1}, and for certain Russian varieties, it exceeds 60 g (PIŁAT 2014). LI and BEVERIDGE (2003) report that the average weight of fruit of the Canadian variety *Indian summer* is between 20 and 40 g·100^{-1} fruit. Each sea buckthorn fruit contains a brown seed with a weight of approximately 16 mg (HARRISON and BEVERIDGE 2002).

On commodity plantations, sea buckthorn is cultivated in the form of shrubs or trees with a height of 2–4 m. Female plants are dominant, and male individuals, which are planted as pollinators, should account for approx. 7–8% of the total. It is most preferred to plant the males in the first row from the side of the most frequent winds, and then in every third row, every 6^{th} or 7^{th} seedling. In practice, the percentage of pollinating varieties may be reduced to

Fig. 2. Sea buckthorn; female flowers and masculine
Source: „Das Buch vom Wurzen", Leipzig, Verlag fur die Frau, 1989

4–5%, which, as a result, allows several extra tonnes to be harvested from each hectare (PLUTA 2014). The most preferred time for planting is either autumn (October) or early spring. The planting stock should consist of 1-year or 2-year-old shrubs which are planted at a spacing of 4 m x 2 m (1,250 plants/ha). When planting poorly-growing varieties, and applying the cultivation in the form of low-growing trees, there is the possibility for increasing the density of the plantings (4 m x 1.5 m). In Poland, on industrial plantations, the average yield is 7–9 tonnes per 1 ha. This is similar to the yields obtained in other European countries. These yields are obtained every second year due to the harvest method applied (cutting shoots with fruit). Therefore, the actual average annual yield per 1 ha is approx. 4 t/ha (PLUTA 2014). When managing the plantation, it is necessary to control weeds, mow the grass, apply mineral fertilisation, sanitary pruning of the plants as well as irrigation during drought, and to protect the plants against diseases and pests. Plants may be infected by fungal diseases, e.g., fusarium wilt (*Fusarium oxysporm*) and verticillium wilt *(Verticillium sp.)*, causing massive drying off of plants as well as trunk gangrene and black cancer. The pests posing the greatest risks include *Rhagoletis batata*, sea buckthorn moth; *Eriophyoidea*, the green sea buckthorn aphid; and sea buckthorn fly.

Characteristics of the sea buckthorn varieties

Sea-buckthorn, as a plant growing in many climatic zones, has undergone natural modification over the centuries, which has resulted in the creation of species differing in numerous characteristics, e.g., the habitat of trees or shrubs, the size and colour of fruits, the length of pedicel, the density of fruit on the shoots, the tendency to drop fruit, and resistance to pests and diseases.

The first sea buckthorn plantations were established in Russia, where 60 varieties were selected from among approx. 150 varieties growing in the wild (Table 1) (Lipowski et al. 2012). The area under commodity plantations in Poland is small. Most often, sea buckthorn shrubs are planted for aesthetic purposes, on allotments in the form of hedges, and in parks. For this purpose, a biotype commonly referred to as 'Nadbałtycki' (or ''Baltic'') is used. As a result of cultivation research carried out at the Research Institute of Horticulture in Skierniewice, the variety 'Jozef' was selected, which requires it to be promoted and introduced to cultivation. Currently, on commodity plantations of sea-buckthorn, German varieties and those registered in Belarus and Russia are cultivated. These varieties include: 'Podarok Sadu', 'Avgustinka', 'Botanicheskaya', 'Nivelena', 'Trofimovskay', and 'Plamiennaya'.

'Podarok Sadu' (Photo 2) is a mid-late variety with slightly ellipsoidal fruits that are orange to orange-red in colour. The fruits ripen at the turn of August and September. The content of vitamin C is 85–166 mg/100 g, sugars 2.6–4,97%, organic acids 1.75–3.6%, and fats 4.6–4,91%. The shrubs have umbrella-like crowns, and reach a height of up to 3 m. It is a frost-resistant variety, yielding a crop of 15–24 kg from a shrub (Szałkiewicz and Zadernowski 2006, Skalij 2007, Lipowski et al. 2012, Piłat 2014).

Photo. 2. Podarok sadu

Source: A. Bieniek

'Avgustinka' (Photo 3) is a variety with spherical, slightly ellipsoidal, orange fruits. The of vitamin C falls within the range of 95–174 mg·100^{-1} g, the content of sugars is 1.1–4.5%, organic acids 1.5–4.3%, and fats 2.7–4.8%). The crop obtained from one shrub is within a range of 12.5–20.5 kg (Skalij 2007, Lipowski et al. 2012).

Photo. 3. Avgustinka

Source: SKALIJ (2007)

'Botaniczeskaya' (Photo 4) is a variety characterised by small, spherical fruits that are dark-yellow in colour. The content of vitamin C is 120–140 $mg \cdot 100^{-1}$ g fruits, sugars 3.1–5,67%, acids 1,60–3.1%, and fats 3,67–5.6%. Up to 2.5 kg of fruit may be harvested from one shrub (SKALIJ 2007, LIPOWSKI et al. 2012, PIŁAT 2014).

Photo. 4. Botaniczeskaya

Source: A. BIENIEK

'Nivelena' (Photo 5) is a mid-early variety. The harvest date is 15–20 August. Fruits are yellow-and-orange in colour. The content of vitamin C is approx. 81 mg/100 g fruit, and the content of fats is 3%. This variety yields excellent crops. Up to 35 kg of fruits may be harvested from one shrub (SZAŁKIEWICZ and ZADERNOWSKI 2006, SKALIJ 2007).

Photo. 5. Nivelena
Source: SZAŁKIEWICZ and ZADERNOWSKI (2006)

'Trofimovskaya' is a mid-late variety. The fruit harvest date is at the turn of August and September. It is frost-resistant. Fruits are oval and oblong, orange in colour. The content of vitamin C is 91,78–183 mg·100^{-1} g, sugars 3.1–5,00%, fats 3,99–4.8%. A crop harvested from one shrub is, depending on the year, from 1.79 to 10.43 kg (SZAŁKIEWICZ and ZADERNOWSKI 2006, SKALIJ 2007, PIŁAT 2014).

'Plamiennaya' is a mid-early variety. Fruit is harvested on 15–20 August. Fruits are oval-shaped, red-and-orange in colour. A crop harvested from one shrub is, on average, 19 kg, up to a maximum of 29 kg from one plant (SZAŁKIEWICZ and ZADERNOWSKI 2006).

Under the climatic and soil conditions of the city of Olsztyn (north-eastern Poland), in experiments carried out at the Department of Horticulture at the University of Warmia and Mazury in Olsztyn, the Ukrainian varieties 'Podarok Sadu', 'Botanicheskaya', 'Trofimovskaya' and 'Otradnaya' were cultivated and assessed. Results for the crop productivity and the quality of fruit were compared to those for the 'Nadbałtycki' biotype, and presented in the following publi BIENIEK et al. 2001, BIENIEK et al. 2007, KAWECKI et al.

2001, KAWECKI et al. 2004ab, KAWECKI et al. 2010, SZAŁKIEWICZ et al. 2007, PIŁAT et al. 2012.

Due to the scientific recognition of the therapeutic properties of sea buckthorn fruit, in many European and Asian countries as well as in Canada, commodity sea buckthorn orchards have been established for several dozen years. Currently, sea buckthorn is cultivated on an industrial scale in Russia, Germany, China, Finland, and Estonia. It is estimated that the area of natural occurrence of sea buckthorn shrubs in Russia, China and Mongolia is approx. 810,000 ha. Commodity plantings in that region have an area of 300,000 to 500,000 ha, while the area under plantation in Finland is approx. 200 ha (SZAŁKIEWICZ and ZADERNOWSKI 2006, KAUPPINEN 2013). According to SZAŁKIEWICZ and ZADERNOWSKI (2006), small plantings have also been established in Poland, particularly in the Suwałki Region, and near Łomża.

Conclusion

The implementation of innovative solutions in agriculture through the introduction of new, novel crops may contribute to the stabilisation and increase in small farm income from agriculture. It should be remembered that sea buckthorn fruit, despite being rich in nutrients, are rarely consumed raw but are primarily a component of many processed multi-fruit products, or a raw material in the manufacture of medicinal products. Therefore, the establishment of the national plantation area must be closely correlated with the needs of the domestic market and export capacity for fruits or processed products. At the same time, sea buckthorn crops may contribute to fulfilling the demand for raw and primary processed products by specific sectors of the food, pharmaceutical, and cosmetics industries.

Translated by KAROLINA ZADROŻNIAK

Accepted for print 2.10.2015

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