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Agro-ecological characteristics of sea buckthorn (*Hippophae rhamnoides* L.) in Azerbaijan

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ABSTRACT

The results of sea-buckthorn breeding in Azerbaijan are discussed. Assessment of the main biomorphological and economical traits of local varieties of sea-buckthorn (Hippophae rhamnoides L.) is given. Discusses the results of studying of resistance to salt stress and structural elements of productivity of the varieties and forms of sea buckthorn. The essential differences between varieties were determined.

Keywords: Breeding, characteristics, sea-buckthorn, varieties, wild forms

Medicinal significance of sea-buckthorn (*Hippophae rhamnoides* L.) is known by people since the ancient times. It is used as medicine, food and feed source, technical purposes, in establishing of protective belt, live fences, as well as in planting of greenery, in prevention of erosion and soil recultivation (Ryazanova, 1997; Eydelnant, 1998; Bukshtynov *et al*. 1985; Thomas and Thomas , 2003). It is a valuable fruit and medicinal plant. Since the ancient times sea-buckthorn has been used in numerous herb collections in folk medicine. Its fruits and leaves were used in Tibetan traditional medicine 1300 years ago.

Sea-buckthorn fruits contain unsaturated fatty acids, up to 3% of organic acids, tannins, flavonoids, vitamins (A, C, B_1, B_2, B_6, E (α, β, γ), K, P etc), up to 12% of sugar,15 micro nutrients and other biologically active substances. Sea-buckthorn fruits contain up to 8 % of fatty oils. In general, there are 190 various biologically active matters in sea-buckthorn. All above mentioned substances are contained in fruits, leaves, seeds and roots of sea buckthorn. That is why sea-buckthorn is a very good immune modulator and immune protector (Eydelnant, 1998; Bukshtynov *et al*., 1985; Fefelov and Smirnova, 2003)

Usage of beta-carotin (provitamin A) contained in sea buckthorn promotes the development of human embryos, normal process of pregnancy, growth and stability of human's body. Sea buckthorn is an efficient agent for prevention of infectious diseases. It refreshes person after serious surgeries, makes blood vessel elastic. Enough quantity of alfa-tocopherol provides normal function of heart, endocrine glands and other human organs. Preventive consumption of products and drugs of sea buckthorn helps to prevent diseases of respiratory organs, gastrointestinal tract, including development of ulcerous and preulcerous processes, and diseases of genital organs (Salatova *et al*., 1974).

More than 250 products of food (jam, compote, juice, fruit wine, vodka, liqueur, soft drinks etc.), medicinal and cosmetic importance are prepared from sea-buckthorn fruits. Sea-buckthorn is a high valuable medicinal plant. Existence of vitamins in the content of fruits resulted that it become named as a poly-vitaminic fruit (Eydelnant, 1998 and Bukshtynov *et al*., 1985).

In modern medicine sea-buckthorn oil is used in anemia, heart diseases, hypertonic, eczema, stomach ulcer and duodenum, in damage of skin by radiant, inflammation of mucous membrane, gullet cancer, in treatment of gynecological and eye diseases (Eydelnant, 1998)

First, in the world factory on production of sea-buckthorn oil was built in 1949 in the Altai (Biysk city). But the limited stocks of sea-buckthorn and capacity of the factory could not satisfy increasing requirements for medical products from sea-buckthorn fruits. For solving the problem of raw material supply the need in finding new stands of this species, extension of existing populations' area through planting and establishment of plantations, studying of various forms, introduction in culture and development of varieties. Broad researches on studying and selection of economic and valuable forms of the sea-buckthorn, growing in various botany-geographical areas were conducted in the Research Institute of Horticulture of Siberia named after M. A. Lisavenko. The first sowings of the seeds, collected from promising forms of sea-buckthorn, have been made in 1934-1935 by M. A. Lisavenko. Numerous forms of wild-growing sea-buckthorn have been studied by Z. I. Gatin. Later in result of breeding works numerous sea-buckthorn varieties were developed (Bukshtynov *et al*., 1985).

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As the plant's leaves also have got vitamins and other valuable substances they are used as useful forage for agricultural animals. Price of sea-buckthorn is not measured only for its use in medicinal and food productions. Sea-buckthorn is valuable forestry species. It has strong capacity to produce root suckers, which give opportunity for its use for mitigation of soil erosion and this is a good way of reclamation of lands, marginalized in agriculture. Because sea-buckthorn usually grows on the upper layer of soil, strongly branches and it has got multi-storied root system as well root tubers are formatted there and by their help free nitrogen of the air is absorbed as well it enriches the soil with the nitrogen as legume plants. That is why it is possible to breed sea-buckthorn in soils without humus, in the interfile grown, even the area which sructure destroyed by mining activities. Use of the sea-buckthorn as a fitomeliorant increases biological productivity of soil and returns them to agricultural circle. Moreover, sea buckthorn is used for afforestation in steppes and fixing river banks.

MATERIALS AND METHODS

Local sea-buckthorn varieties from the field genebank of AzerbaijanGenetic Resources Institute (AGRI) were chosen as research material for this study. Phenological phases, growth, biomorphological description and productivity, fruit quality traits, resistance to disease and pests were studied by using the common description methods of sea-buckthorn (Kondrashov, 1977 and Michurinsk, 1980). The scheme "the description of the samples of sea buckthorn in the field conditions" following indicators are taken into account: site location, altitude, relief, collection site location, genus, species, gender, name of form, height of plant, crown shape, main branch location, crown diameter, crown density, plant thorniness, length of thorns on fruit shoots, leaf color and fruitage degree) In laboratory conditions the indicators identified are size of leaf blade, number of fruits developed from one fruit bud, fruit stem length, color, shape and size of fruits, strength of peel for ripping, weight of 100 fruits, fruits taste, color and shape of seeds, number of seeds in fruits (%), the biochemical composition of fruits like content of dry matter in the pulp, oil, vitamin C, carotinoids, sugar, acids. To define the level of branch thorniness 6 scoring scale was used:

0- thornless

1-very weak-thorned, the length of thorns less than 1cm, up to 3 thorns on each 10 cm of fruiting shoot;

2- weak-thorned, the lengths of thorns 1-2.5 cm, up to 4 thorns on each 10 cm of fruiting shoot;

3-moderate -thorned, the length of thorns 2-3.5 cm, up to 5 thorns on each 10 cm of fruiting shoot;

4-strong-thorned, thorns are strong and double, length up to 5 cm, 4-6 thorns on each10 cm of fruiting shoot;

5-very strong-thorned, double-tripled thorns, strong, of 6-7 cm in length, up to 5 and more thorns on each 10 cm of fruiting shoot.

During description different fruit shapes were characterized as Rounded (1.00-1.19 mm), Oval (1.20-1.39 mm) and Cylindrical (1.40-1.59 mm). Sea buckthorn fruits were arranged into 3 groups by their size: Small-less than 6 mm; Medium-from 6 to 7.5 mm and large-more than 7.5 mm. Sea buckthorn fruits were arranged into groups by their color: yellow, yellowish-orange, orange, reddish-orange, red. All measures, if possible were made in the middle part of crown (or bush) of the plant. The degree of fruit ripeness was approximately defined by its taste. Using sliding calipers longitudinal and cross-section length of typical fruits and seeds were measured. For this 10-20 fruits and seeds were measured and mean value was considered.

Diagnostics of plant resistance to stresses were determined by the method G.V. Udovenko (1988).The essence of this method is the determination of the ratio of the stress-depression pigment complex of the photosynthetic apparatus (chlorophyll a + b) of the experimental variant (in a solution of 2% NaCL) to control (water). For assessing of the salt resistance of plants leaf rings of 0.6 cm in diameter of each studied samples were placed in the test tubes both in the control and experimental variants. Distilled water was used in a control variant, while 2% solution of NaCl was used for salinity environment in the experimental variant. After keeping of tubes in the dark condition for 24 hours, the solutions were poured out and 96% solution of alcohol was added into each tubes. After 5 days, optical densities of the chlorophyll pigments were measured by the spectrophotometer in a wave length of 665 and 649 nm. The ratio of the concentration of pigments in the control to the experimental variant indicates the resistance of plant sample studied, which the higher value of this indicator evidenced the higher resistance.

RESULTS AND DISCUSSION

There are natural brush woods of sea-buckthorn with in 15 regions of the Azerbaijan Republic. These ancient floristic regions of Azerbaijan are the origin of several families and genera including *oleaster (Elaeagnus L.)* and sea-buckthorn which are representatives of the *Elaeagnaceae Lindl* family. It is supposed that these genera's migration to the north has started from here (Musayev, 2007)

Sea-buckthorn used to be a tree-shaped plant in subtropical conditions. As a result of climate getting cold in the Pleistocene and posterior periods the bush-shape began to develop. However, sea-buckthorn kept its biological and morphological peculiarities which are characteristic of tropical

aboriginal wooden plants. It became obvious that towards the end of Cretaceous period the Caucasus with its humid climate was covered by tropical and subtropical forests but during freezing periods the tropical forest was nearly destroyed. However the Talysh Mountains not very exposed which resulted in conditions to maintain the tropical forest components of the Hirkan flora. This is the reason why the Talysh Mountains plays an exceptional role in present very rich cover of vegetation in the country (Vavilov, 1926 and Vavilov, 1931). Taking into account Hirkan flora's autochthonous origin, we consider that sea-buckthorn has been spread to the republic's area and neighboring countries directly from the Talysh Region. As the academician N.I. Vavilov considered, areas of origin are distinguished with periphery by the speed of the variety and form generation as well their great number. Like other fruit-berries sea-buckthorn's exists in many wild forms, which creates an opportune condition for specifying thoughts concerning to the origin and migration.

Wild sea-buckthorn brushwoods are widely spread in most regions of the Republic - Guba-Khachmaz, Shaky-Zagatala, Shirvan, Talysh, Garabagh, Nakhchivan AR and etc. While natural sea-buckthorn populations are mainly spread in Ismayilli, Shamakhi, Aghsu, Gabala, Shaky, Gakh, Zagatala, Guba, Gusar and etc. regions. Sea-buckthorn is growing very well almost in all places, being part of riparian forest 'tugay'. Sea buckthorn is dioecious plant, meaning that there are separate male and female trees. The female flower has no nectaries. Pollen is distributed by the wind. In Azerbaijan the height of sea-buckthorn is 2-5 m, sometimes 10m, and it is tree or bush. Trunk diameter is about 30cm. The weight of 100 fruit is 8-25 g, sometimes 30-35 g. Fruits of local forms are small, barrel shaped, longish and round, yellow, yellow-orange colored. Seeds are big, less juicy, and thorny. Fruits ripen after 20th October. Productivity is low, 3-5 kg, sometimes 7-8 kg per bush. Populations of sea-buckthorn existed in the different regions were characterized for their morphological, biological and biochemical traits (Negri,2012;Akparov and Musayev, 2012 ; Musayev and Akparov , 2011).

There are different forms of the sea-buckthorn according to the height of plants, dimensions of their leg, branches and twigs as well fruits dimensions and their colors, their thorniness degree, shape of the umbrella and chemical content of the fruits in the different parts of the Sea-buckthorn aerials. Origination of such different forms depends on soil and climatic condition. The characteristic features for sea-buckthorn spread in the Southern Caucasus in whole are follows: high, strong thorny, narrow leaves, great number of fruits per fetus branches approximate length, small fetuses, brightness of the fruits, sour and tart taste, a big amount of oil, vitamin "C" and trifle of carotinoids dry substance is in a higher per cent. However, fewer thorny and without thorns, big-fruited forms possessed high percentage of vitamin "C" and carotene of this ecological-geographical population are met too. Ninety forms of the sea-buckthorn distinguished for the various morpho-biological indexes were revealed at the result of the conducted researches by our institute collaborators in the territory of Azerbaijan Republic. During the investigation – river banks, shores and other aerials of sea-buckthorn inhabitants their major concentrated places and aerials contours and outlines were defined. Also, depending on their aerial of spread, productivity, colour of fruits, shape and other botanical features as well as biological characteristics of wild sea-buckthorn were defined. It was realized that more productivity sea-buckthorn forms are met on the river costs of Shinchay, Filfilichay and Dashaghylchay, however colour of their fruits are usually yellow; sometimes forms with orange-yellow fruits are met too. On the river-banks of Kirdmanchay forms with orange, rosy colour but small foetus and big seed fruits were spread. We divide 90 form diversities of the sea-buckthorn revealed in the territory of the republic into 4 groups according to their foetus dimensions and number of seeds in a fruit in per cent (Imamaliyev and Musayev, 2001)

Group 1: Weight of 100 fruits is 8-15 g; seed consists of 7-10, 8 % of the fruit; juice obtaining is not more than 25-27 %. These forms are usually dominants in natural brushwood as well 70 % of the whole brushwood consists of them.

Group 2: weight of 100 fruits is 16-20 g; seed is 7 % of the fruit; juice obtaining is 30-35 %. Probability of these forms existence in the natural brushwood is 20 %.

Group 3: these ones usually have got bigger fruits and weight of 100 fruits is 21-30 g; seed is 6 per cent of the fruit; juice obtaining is 48-50 %. Probability of these forms existence is 8 %.

Group 4: these are big fruited forms; weight of 100 fruits is 31-35 g; Seed is 4, 7 % of the fruit; juice obtaining 60-63 %; probability of such forms existence is not more than 2 % and it is usually met in more inaccessible areas.

Sometimes forms are also rarely in natural brushwood, in which fruits are bigger (but fruits color are yellow); weight of 100 fruits is 40 g; juice obtaining of them is 65 per cent; seed is 3-4 % of the fruit. However, such accessions are met rarely in ratio of 10.000 plants. We suppose that, local people destroy these productive and big fruited plants for the reason of quick and much harvest. On the result of it gene pool of perspective forms is destroyed in natural brushwood of the sea-buckthorn.

Sea-buckthorn was known from the ancient time, however it had no cultured variety. Peoples partly provided their sea-buckthorn fruit need with natural brushwoods. Dense growing and more thorniness of wild forms cause several difficulties . In most regions branches with fruit are cut and harvested fruits at home. Such purchase of fruits causes mass destroying of wild sea buckthorn brushwoods which is inadmissible because wild sea-buckthorn populations are valuable genepool and contain many positive traits and genes formed as a result of long term phylogenetic development. Because can be found here perspective samples that have valuable biological and economic characteristics. 'Shafa' - the first local variety of sea-buckthorn - was created by analytic breeding method in Shaky region (Imamaliyev and Musayev, 2002; Musayev and Imamaliyev, 2001).

Testing of varieties of sea buckthorn from the Russian Federation in three climate zones (Apsheron, Karabakh, and Shaky) did not justify the expected results. The varieties were found to be less fertile with a short vegetation period and of low tolerance to diseases and pests. Taking into account the national economic importance of biodiversity, the Genetic Resources Institute of the Azerbaijan National Academy of Sciences (AGRI) has started to restore the gene pool collection of 1972 in order to create high-yield and qualitative varieties of sea-buckthorn from local forms and introduced Altai varieties. As a result, 90 different local wild samples of sea buckthorn which have an important role in the development of advanced forms and varieties were collected, and the place of their distribution and density were identified. These forms sharply differ in many morphological characteristics - shape, color, size of fruit, bush shape, thorniness degree, as well as taste, etc.

The use of ecologically-separated forms of sea-buckthorn for hybridization allowed us to create a rich hybrid material. As a result of experiments the cultivars 'Shafa', 'Zafarani' (female varieties) and 'Tozlayan' (male variety), which are suitable to local soil and climatic conditions, have been created. These are high-yield varieties (18-25t ha^{-1}), big-fruited (each fruit's weight is 50 - 60 g), weak-thorned (Zafarani, Tozlayan) or thornless (Shafa). In the natural brush woods of the Azerbaijan environment, sea-buckthorn fruits ripen towards the end of October (Table 1). The new cultivars have different maturation periods (from early August to the second half of October) and are resistant to diseases and pests. These new varieties of the sea-buckthorn are of universal character: they can be used as fresh fruits, to prepare jam, juice, oil, liqueur, stewed fruit and much more. Thanks to positive bio-economical peculiarities, the profitability level for the products is high. From a recent hybridization between forms of different origin (Siberia x Azerbaijan) three varieties of sea-buckthorn with early maturation (ultra scope matured) fruits (July) and with oil content of 7.1 % were obtained.

Table 1 : Bio-morphological indicators of varieties and forms of sea-buckthorn (10 years old plants)

Indicators	**Varieties and forms**					
	Zafarani	**Shafa**	**Tozlayan**	**Karlik**	**Wild**	**September**
Plant height (cm)	290	300	470	230	300	320
Forms of crowns	Spreading crown	Spreading crown	Spreading crown	Medium spreading crown	Spreading crown	Spreading crown
Leaf size (mm)	84-93 ×13-12-15	75-88 × 7-8-10	70-80 × 8-9	45-50 × 4-5	70-80 × 5-8	75-80 × 10-12
Degree of flowering	5	5	5	5	5	5
Degree of thorniness	3	0	3	5	5	3
Time of maturation	1-5 August	15-20 October	-	5-10 November	20-25 October	10-15 September
Wt. of 100 fruits (g)	60	50	-	25	25	40
Size of fruit (mm)	10-11	12-10	-	6-7	7-5	10-12
Form of fruits	Oval	Elongated	-	Elongated	Elongated	Elongated
Consistency of pulp	Juicy Mid-density	Juicy Density	-	Low juicy Density	Low juicy Density	Juicy Density
Tasting score:						
a) fresh condition	4,5	4	-	3	2	2
b) juice	4,5	4	-	4	3	3

To provide for people's need and for other purposes, the creation of productive, big-fruited, rich in biological active matters, more juicy, thornless or weak thorned, and resistant to diseases and pests sea-buckthorn varieties is the main problem for breeders in modern time.

Brief characteristics of the local varieties

'Shafa' variety was realized in the Azerbaijan Republic in 1991 year. The variety was obtained by selecting from the natural sea-buckthorn brushwood grown in Shinchay basin of Shaki region of Azerbaijan. The variety is thornless, late ripening and productive. Productivity of a tree or bush is 16-23 kg. It is resistant to pests and diseases. It is a universal variety. The oil content ranges between 3,75-4, 2 % depending on the ecological condition of the cultivated site. The fruit colour is usually orange or orange-yellow, weight of 100 fruits is 50-52 g. It tastes sour-sweet. Peel of the fruits is thin, flesh and is not soft. It is long and is brown color. Seed is elongate, dark-brown or black color. The seed makes up 3,4- 3,6 % of the fruit, 1000 seed weight is 17 g. Fruit shape is attractive. Dimensions of fruits are: 10-13.2 x 7.4-9.6 mm. Consistence and juiciness of the plump is juicy and dense. It is resistant to diseases and pests. Transportation ability of the fruits is low. Main purpose of the variety is universal character: can be used as fresh fruits, to prepare jam, juice, liqueur, stewed fruit and much more. Tasting value mark: a) in fresh condition - 4.0, b) juice - 4.0.

'Zafarani' variety was realized in 1994. This variety was got from hibrid population by selection. It was obtained from hibridization of population of local male variety with 'Novosty Altaya' introduced from Siberia. Variety is weak thorny, high productive, fruits ripen in August. An average productivity of one plant is 22-31 kg, maximum is 58 kg. Average oil content is 4.75%. 'Zafarani' variety is resistant to diseases and pests. The colour of the fruits is yellow, yellow-orange, orange, weight of 100 fruits ranges between 55-60 g. It tastes sour and sweet. The stalk is short, about 1.5-2 mm. Fruit peel is thin, the flesh is not soft. Seeds are small, brown or dark brown colour. Seeds make up 2.7 % of the fruit. 1000 seed weight is 14 g. Fruit's shape is attractive. Dimensions of fruits are: 10.4-11.0 x 8.8-10.2 mm. Consistence and juiciness of the plump is juicy and of mid-density. Transportation ability of the fruits is low. Main purpose of the variety is universal character: can be used as fresh fruits, to prepare jam, juice, liqueur, stewed fruit and much more. Tasting value mark: a) in fresh condition - 4.5, b) juice - 4.5.

The 'Tozlayan' variety (male variety): The variety was realized in 1994 year. It was obtained by the selection from the natural sea-buckthorn population spread in the area of Shaky of Azerbaijan Republic. It is mid-thorny, resistant to diseases and pests. As a result of investigations it was defined that male individuals of the sea-buckthorn is not less polymorph than female ones. Different male forms on the result of a strong polymorphism not only have distinct pollen productivity, they also effect the productivity and fruit quality of female plants. Concerning to these, selection of perspective sea-buckthorn male varieties pollinators were recommended. The experiments showed that 'Tozlayan' variety distinguishes mainly according to pollens fecundity degree, and this index is 96,4 %. As pollens of this variety have very strong survivability they are very useful for farming, because weak survive ability of male plants leads to much location of male individuals in sea-buckthorn gardens, which in turn reduces productivity. As a rule in the sea-buckthorn gardens per each 5-6 female plant one male plant is enough, whereas due to very high survivability of the 'Tozlayan' variety's pollen it is required to grow one male plant ('Tozlayan' variety) per each 8-10 female plant in the gardens.

One of the main problems of modern agriculture is working out theoretical bases of high productivity. Production of varieties fruitful, resistant to environmental factors, adaptation is the most actual

issues for modern selection. According to the received results in the varieties Shafa Tozlayan, as well as in the sample of September, depression of salt stress were not detected. They are characterized by a high content of chlorophyll. In comparison with the studied varieties, samples Zafarani, Karlik and Novost Altaya can be considered medium resistant to salt stress (Fig. 1) (Musayev and Huseynova, 2008).

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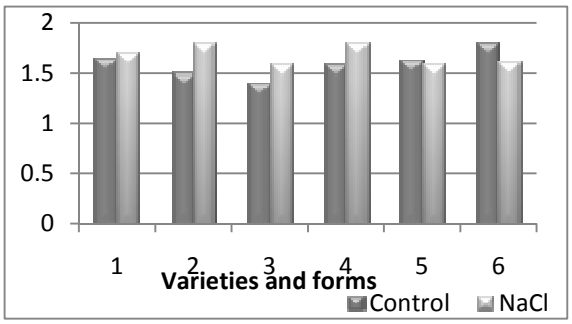

1. Tozlayan 2. Shafa. 3. Novost Altaya 4. September5. Zafarani 6. Karlik

Fig. 1: Change of the amount of chlorophyll under the influence of salt stress in the varieties and forms of sea-buckthorn berries

All experiments showed that, productivity of seabuckthorn depends on some structure elements (Table 2). It was known that, there are many positive relations between plant productivity and fruit number (r = 0.84), weight of 100 fruit, lenght of productive branch (r = 0.76), number of productive branches (r = 0.51), productivity index of branches (r = 0.85), height of fruits (r = 0.63) and fruit diameter (r = 0.84). Although there are many positive correlations between structural elements of form and samples of investigated seabuckthorn, but the closest positive relation were determined between 100 fruit weight (r = 0.87), productivity index of branches (r = 0.85), fruit number of a blossom (r =0.84) and fruits diameter (r = 0.84). The essence of determination of structural elements and correlation of investigated form and samples had defined the genetic possibilities of seabuckthorn. These indexes have a great importance on production of new productive samples. For example, in seabuckthorn selection improvement of fruit weight (productivity index) must be achieved. Productivity index depends on fruit number (r = 0.60) of unit branch lenght and average weight of fruits (r = 0.68). Therefore, in the selection of new varieties, advisable variant of hybridization, is the crossing of the parental forms, which have a maximum weight and number of fruits (Musayev, 2007).

Table 2: The main elements of productivity of sea-buckthorn varieties and forms of Azerbaijan

Varieties and forms	Productivity (kg plant^{-1})	No. of fruit floral buds^{-1}	Wt. of 100 fruits (g)	Fruit length (mm)	Fruit diameter (mm)	No. of fruit bearing flower buds m^{-1}stem of plant	No. of fruit per unit length	Fructiferous stem length (cm)	No. of productive stems plant^{-1}	Coefficient of productive stems
Wild form	4.3	4	20.0	7.2	6.0	200	8.4	16.8	152	1.7
Perspeктiv	14.5	3	42.5	10.0	8.5	131	3.3	20.8	498	1.4
Novost ltaya	1.5	2	37.5	9.7	8.4	60	2.3	7.6	230	0.9
Shafa	20.0	5	50.5	11.7	8.7	123	4.0	17.4	571	2.0
Zafarani	27.3	6	59.9	10.4	10.1	136	7.5	21.4	285	4.5

From a recent hybridization between forms of different origin (Siberia × Azerbaijan) three varieties of sea-buckthorn with early maturation fruits (July) and oil content of 7.1 % were obtained. More perspective and threatened forms of natural populations of sea-buckthorn spread in the Republic were not yet evaluated and included to the collection. Therefore conservation of plant genetic diversity of sea-buckthorn existed in Azerbaijan Republic, selection of productive samples, evaluation and protection are one of the most important problems in modern time.

Taking into account economic efficiency the growing of above mentioned sea-buckthorn varieties can have great perspectives not only in Azerbaijan, but also in countries with similar climatic conditions. The results can be used in the breeding of new productive forms and varieties.

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