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PHYSICAL AND MECHANICAL PROPERTIES OF *Crataegus submollis* Sarg. WOOD AT INTRODUCTION IN BELARUS

The results of research of some physical and mechanical properties of *Crataegus submollis* Sarg. wood, formed in the conditions of introduction are presented in the article. By using standard wood research methods it was found that the average width of the annual ring is (2.76 ± 0.71) mm, 89% of which is taken by the latewood. Of all the species growing in Belarus hawthorn produces the most dense (ρ_{12} = (912.2 ± 6.6) kg/m^3), solid (σ_{12} compression along fibers 73.2 MPa) and hard (H_{12} in cross section 108.2 N/mm^2) timber. Hawthorn wood is characterized by high dynamics of water absorption and belongs to strongly shrinkable species, the ratio of its volume shrinkage is (0.72 ± 0.02)%. A supposition was put forward about good prospects of creation of complex *C. submollis* plantations and about this species introduction as an additional species in artificial forest stands.

Key words: wood, hawthorn, *Crataegus submollis*, introduction, physical and mechanical properties of wood, prospects of usage.

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ФИЗИКО-МЕХАНИЧЕСКИЕ СВОЙСТВА ДРЕВЕСИНЫ БОЯРЫШНИКА МЯГКОВАТОГО *Crataegus submollis* Sarg. ПРИ ИНТРОДУКЦИИ В БЕЛАРУСИ

В статье приведены результаты исследований некоторых физико-механических свойств древесины боярышника мягковатого *Crataegus submollis* Sarg., сформированной в условиях интродукции. Путем использования стандартных методик исследования древесины было выявлено, что средняя ширина годичного слоя составляет (2,76 ± 0,71) мм, 89% которой занимает поздняя древесина. Из всех произрастающих в Беларуси пород боярышник формирует наиболее плотную (ρ_{12} = (912,2 ± 6,6) кг/м^3), прочную (σ_{12} на сжатие вдоль волокон – 73,2 МПа) и твердую (H_{12} на поперечном разрезе – 108,2 Н/мм^2) древесину. Древесина боярышника характеризуется высокой динамикой водопоглощения и относится к сильно усыхающим породам, коэффициент ее объемной усушки составляет (0,72 ± 0,02)%. Выдвинуто предположение о перспективности создания многоцелевых плантаций боярышника мягковатого и введения этого вида как дополнительной породы в лесные культуры.

Ключевые слова: древесина, боярышник мягковатый, *Crataegus submollis*, интродукция, физические и механические свойства древесины, перспективы использования.

Introduction. Timber, obtained in the conditions of Belarus from local breeds, is characterized by medium or low characteristics of physical and mechanical properties of wood. This leads to the forced importation of wood of so-called "valuable" species, with better operating properties. The main imported species are hardwood ones – beech, walnut, oak and wood of tropical trees, the average price of which according to the National Statistics Committee of Belarus is up to 5,000 US $ per m^3 [1]. In addition to high decorative properties, wood of these species has good hardness and strength coefficients and that enables them to be used widely for production of luxury furniture, floor, interior elements, machine parts and for the ornamental production. One of the promising areas of import substitution is species searching of introducents capable in the conditions of Belarus to form high-quality wood, and in the long term replace imported foreign species.

Active research of wood properties of rare, and often endemic [2, 3, 4] and introduced [5, 6, 7] species is carried out in the countries of Western Europe. It is believed that a weak study of the wood properties is one of the obstacles to the widespread use of timber of such species as *Corylus colurna*, *Ostrya carpinifolia*, *Sorbus aucuparia*. It was found out that some of the exotic species growing in Europe, such as *Robinia pseudoacacia* are not inferior in strength [8] and biological stability [7] to tropical species, exceeding significantly the local species wood.

The most high-density and solid wood in the conditions of Eurasian temperate climate is formed by the plants of *Crataegus* (Hawthorn). These deciduous plants of the Rosaceae family are valued

for high decorative qualities, the fruit is widely used in food and pharmaceutical industries [9]. Since the mid-19th century many species of hawthorn were introduced in Belarus, which later became widespread in settlement gardening, became an ornament of parks, arboreta and estates [10]. In the collection of the Central Botanical Garden of NAS of Belarus according to 2012 inventory results 131 species and intraspecific taxa of plants of the hawthorn genus [11] are cultivated. Currently, hawthorn is widely cultivated in China, Italy, Turkey, Iran, Spain and other countries as fruit crops. Hawthorn is also widespread in the pharmaceutical industry in France, Mexico, Romania and other countries [12].

Crataegus submollis Sarg. is characterized by good winter hardiness and high-growth, which allowed it to be widely used in the creation of green areas in Belarus and many other countries of Central and North Europe [10]. The natural habitat of *C. submollis* stretches along the Atlantic coast of North America, where the species grows on damp slopes, on the forest edge. In nature, this tree is up to 8 m high, with the trunk diameter up to 30 cm, often multi-stemmed or bushy growing. Hawthorn is noted by its durability, the duration of plants life is up to 300 years.

Despite the high prevalence of this type the information about its wood quality is very fragmented, and there are no scientific data on the properties. The aim of our work was to study the basic physical and mechanical properties of the wood of this introduced species, formed in our country.

Materials and methods. Sampling and sample preparation was carried out in accordance with Standart GOST 16483.0-89. From *C. submollis* timber with the upper cutting diameter of 11 cm and 1,1 m long (the plant age is 25 years) edge-surfaced lumber was obtained, which was dried with painted butt-ends at indoor conditions for 3 months. Then standard samples of 20×20×30 mm were prepared, which were further conditioned at indoor conditions for 1 month. The calculation of amount of sampling (number of samples) for each test variant was calculated to achieve the probability level of 95%. The study of the physical and mechanical properties were carried out according to the interstate standards [13–17].

Mechanical properties were tested on the universal testing machine MTS Insight 100, primary data processing was carried out in the program Test Works 4.

Physical and mechanical testing included determination of: average width of the annual ring, latewood content in the annual layer, density (basic and at humidity of 12%), shrinkage factor (in radial and tangential directions, by volume), water absorption, compressive strength along the fibers, and hardness of butt and side (tangential and radial) surfaces.

Results and discussion. According to the structure of the annual ring hawthorn belongs to the sparsi-vascular hardwood species with moderately expressed wood texture. The species is a heartwood, light brown with pink tinge nucleus gradually becomes pale yellow sapwood also having a light pinkish hue. Annual layers are of uneven width, clearly visible in a cross section, their boundaries are uneven, slightly wavy. Narrow light summer wood gradually becomes latewood, it becomes darker to the outer boundary of the annual ring. Annual layers are poorly visible on the longitudinal sections. Wood rays are numerous, narrow, clearly visible only on strictly radial cuts (splits) as light brown with a pink tinge shiny strips about 0.5 mm wide. The vessels are not visible.

In conditions of Belarus, *C. submollis* is characterized by high radial growth. The average width of the annual ring is (2.76 ± 0.71) mm (table). It is 30–40% higher than that of native hardwoods such as oak and ash, and is only a little bit lower than hornbeam growth [18]. 89% of the annual ring width is taken by the dark-colored latewood.

Physical and mechanical properties of hawthorn wood in conditions of Belarus

Wood property		Number of samples, n	Average value, X_{cp}	Standard deviation, S	Average error, S_y	Variation coefficient, υ	Relative accuracy, P_y
The average width of the annual ring, mm		15	2.76	0.71	0.18	25.73	14.26
The content of latewood, %		15	89	2.0	0.01	2.25	1.25
Density, kg/m^3	W = 12%	12	913.17	6.60	1.91	0.72	0.46
	basic	12	687.53	7.26	2.10	1.06	0.67
Shrinkage factor, %/%	radial	12	0.18	0.016	0.005	8.78	5.58
	tangential	12	0.32	0.016	0.005	5.05	3.21
	on volume	12	0.72	0.023	0.007	3.23	2.05
Water absorption (after 20 days), %		12	57.2	0.71	0.16	1.27	0.60
Compressive strength along fibers, MPa		24	73.19	3.74	0.76	5.10	2.16
Hardness, N/mm^2	cross section	10	108.6	4.10	1.30	3.77	2.70
	tangential	10	69.7	4.45	1.41	6.39	4.57
	radial	10	67.6	3.53	1.12	5.22	3.74

Of all the species growing in Belarus *C. submollis* generates the densest timber. Its density at the standardized moisture level averaged (912.2 ± 6.6) kg/m^3. Basic density is (687.5 ± 7.3) kg/m^3, which is 25% less than the density at 12% humidity. For most local species differences between these density expressions are from 16.5 to 19.5% [18]. Such significant difference of hawthorn is an indirect indication of the high propensity of its wood to swell, and, consequently, to shrinkage.

Results of the shrinkage study of hawthorn wood by the standard method confirmed this assumption. After drying one percent of bound moisture the hawthorn wood volume is reduced by (0.72 ± 0.02)%, allowing it to be placed among the highly shrinkable species. There is a significant shrinkage anisotropy in the transverse directions. The total tangential shrinkage in the tangential direction is almost 2 times higher than the radial one, the shrinkage non-uniformity coefficient is 1,78.

Shrinkage of hawthorn wood in the radial direction (shrinkage factor is 0.18%) is low and coincides with that of oak, ash and pine trees, and in the tangential direction the hawthorn with the coefficient of 0.32% compares well with the most shrinkable species – beech and hornbeam.

Hawthorn wood is characterized by high dynamics of water absorption (Figure). Particularly intense humidity increase process of samples immersed in water occurs during the first 24 hours, during which the humidity increases from 0 to 45.9%. After that, as the maximum moisture absorption approaches, the moisture increase slows down dramatically. Hawthorn samples moisture stable state at the indoor conditions is already obtained at the third day, while hornbeam wood reaches it after 7 days, and willow – after 30 days [19]. The high rate of water absorption of hawthorn can be attributed to advantages of this type of wood, as it is an indirect evidence of a good material saturation property by protective and decorative coatings. Maximum estimated humidity of hawthorn wood, which could theoretically be reached by the hawthorn wood at long-term storage in water, is obtained by the well-known formula through its base density [18], and is 80,1%. This is much higher than the humidity stable state (W = 57.2%), which was maintained during the laboratory experiment from the 3^d to 20th day. Obviously, such a difference is the consequence of the presence in the heartwood of a substantial volume of isolated cavities of anatomical elements, penetration of water into which is greatly hindered.

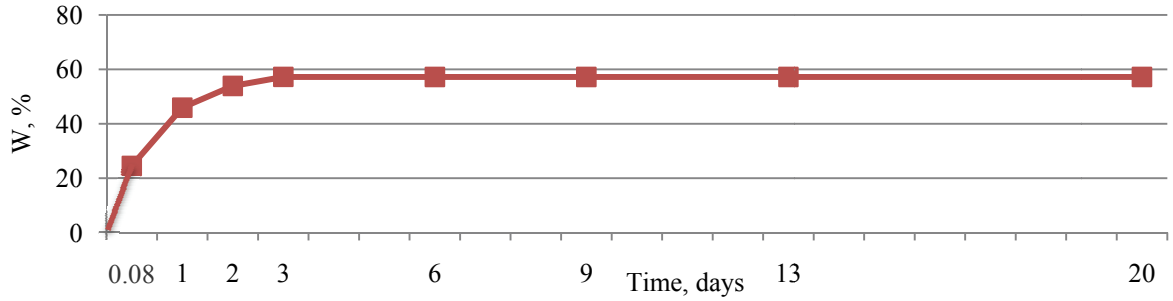
Durability of hawthorn wood at compression along the fibers is higher than that of all naturally growing species in Belarus, surpassing the strongest of them: 22% – hornbeam, 24% – ash, 27% – oak. Compressive strength in hawthorn wood is higher than in such high-strength imported species as beech, walnut, teak, iroko and achieves the strength of black locust and merbau.

In the soil and climatic conditions of Belarus *C. submollis* forms the most solid wood (Table). Static hardness of hawthorn wood in a cross section is higher than in the longitudinal ones 37.8–35.8%, which is not typical for hardwood. Such percentage difference is more characteristic to species with low density and low content of mechanical tissues, such as cedar, fir, linden and spruce [18]. Differences of hawthorn wood hardness in the tangential and radial directions are not statistically reliable.

Conclusions. 1. Widely cultivated in Belarus introducent *Crataegus submollis* Sarg. is characterized by good winter hardiness and rather high growth rates – an average radial growth rate is 2.76 mm per year. Under the conditions of our country, it is able to grow in the form of a tree of a second magnitude, by 25 years already creating business assortments.

2. According to macroscopic structure the hawthorn wood belongs to sparsi-vascular hardwood species with moderately expressed texture and rather high decorative properties due to the core color and medullary rays.

3. In the soil and climatic conditions of Belarus *C. submollis* forms the most dense, firm and solid wood, and it is significantly superior according to these parameters than local species. Its wood has a high rate of water absorption and tendency to shrinkage and swelling.



The dynamics of water absorption of *C. submollis* wood

4. Wood with such a unique set of physical and mechanical properties could potentially replace part of imported tropical species, widely used in the production of parquet flooring, components operating at high loads, and decorative products.

5. We believe it to be a promising direction the study of the possibility of creating multipurpose plantations of *C. submollis* in Belarus, and introduction of this species as an additional one into forest plantations to improve stability, aesthetic and economic value of forest plantations, etc.

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