Volumetric Characteristics of Padus Asiatica Kom. Trunk Timber in Primorsky Krai

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Abstract. The subject of the study in this work was Asiatic cherry Padus Asiatica Kom. There is no data on volume characteristics of Asiatica cherry stem wood in the reference literature at present time. Lack of normative and reference materials brings certain difficulties in calculation of stock per unit area in natural and cultural phytocenoses. The aim of the study was to develop a scale for determining the height grades of stands and compilation of a volumetric table for resource assessment of Asiatic cherry stem wood reserves. Experimental material is presented in the amount of 74 accounting trees. The generalizing curve of the relationship between heights and trunk diameters of the entire set of measured trees was used as the basis for calculating the scale of height grades. This curve was calculated as the arithmetic average of height measurements for all thickness stages. A scale for determining the height grades of stands was developed. The fraction of bark in percentage was determined. Volumetric tables for trunks of Asiatic cherry were compiled. It is established that accuracy of definition of a stock is in admissible limits ± 15%. Volumetric tables for three height grades can be demanded in forest management works, and also are recommended for application to scientific employees and workers of forestry at definition of resource potential and volumetric characteristics of Asiatic cherry trees in natural and cultural phytocenoses.

Keywords: Asiatic cherry · Elevation discharges · Volumetric tables

1 Introduction

It is difficult to name the total number of cherry species, since different authors refer some species to other genera Cerasus Mill. And Prunus L. Apparently, there are about 20–35 species. The range of the genus covers vast areas of Eurasia, North and Central America [1, 2]. In the territory of Siberia and the Russian Far East, 4 species of cherry trees naturally grow: Prunus Padus, avian Padus avium Mill, Maak P. maackii (Rupr.) Kom., Maximovich P. maximowiczii (Rupr.) Sokolov, and cherry P. ssiori (Fr. Schmidt) Schneid. in Handb. According to Vorob'ev [3], Asiatica cherry Padus Asiatica Kom. (Prunus padus L. var. Pubescens Regel et Till.) replaces the Prunus Padus cherry in the

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Far East [4]. Tsarenko [5] noted a different ratio of flavonols in fruits of P. avium Mill from central regions of Russia and from the Far East, which, in the author's opinion, can serve as an additional taxonomic sign for these species. The chemical composition of cherry fruits and the development of large-fruited varieties were studied in [6, 7].

Asiatic cherry has a wide distribution in the Primorye, the Amur region, Sakhalin and Kamchatka. It grows along the banks of rivers and brooks, on spits, among valley mixed forests and shrubs, everywhere except in swampy areas. In the forest, as a rule, cherry trees are small in size, barely reaching 15–18 m in height with a diameter at breast height of 28–32 cm, in open spaces the diameter greatly increases to 34–36 cm [3]. Bark of cherry can be dark brown or dark gray, smooth or slightly cracked. The shoots are pubescent, grayish-velvet, and leaves have red pubescence along the main vein or with red beards in the corners of veins [8, 9]. Leaves are elliptic, 8–14 cm long and 5–8 cm wide, acuminate, dense. Flowers are white, 1–1.2 cm in diameter, in long, up to 12 cm hanging tassels, fragrant. Fruits are glossy black squares, 7–8 mm in diameter, mature with greenish-brown flesh, sweet and astringent, with a characteristic odor of bitter almonds. Real seed production per generative shoot of Asiatic cherry with an average length of 0.69 ± 0.14 m amounts to 7 ± 2.3 bunches with 5 to 7 fruits [10]. It blossoms in May, following the blossoming of leaves. Fruits in southern Primorye ripen in late July-August, in the north in late August-September. Asiatic wild cherry is a winter-hardy and fast-growing species, tolerates slight shading, but develops better and bears fruit more abundantly in well-lit places. It prefers fertile overlying, fresh or wet, but sufficiently drained soils [11]. The wood consists of vascular, fibrous tracheids, heavy and radial parenchyma. The boundary of the annual ring is clearly expressed in the form of a flattened flock of elements (fibrous tracheids, parenchyma, and vessels) in 3–5 layers. The wood is dispersed-vascular, with some tendency to be ring-vascular, with light yellow sapwood and brownish kernel, ductile and resilient, suitable for various household handicrafts. Green and brown dye can be extracted from its bark [12, 13].

Asiatic cherry has a complex of positive qualities. It is a soil-improving and soil-strengthening tree. Bird cherry is known for its valuable decorative, technical and medicinal properties [4, 5, 8, 11, 14–17].

Thus, considering the high scientific and economic importance of Asiatic cherry, there is a natural need for the development of regulatory and reference materials for the resource assessment of stocks of stem wood of this species, which are currently absent. In addition, landscaping of cities and towns should be organized on the principles of a rational planning system. In turn, a rational approach to green building is impossible without knowledge of the volume and quality characteristics of stem wood, which is especially important in the reconstruction of old dying crop-phytocenoses and determination of the compensatory value of green spaces [13].

The aim of the work is to develop a scale for determining the height grades of stands and compiling a volumetric table for the resource assessment of stem wood reserves of Asiatic cherry.

2 Materials and Methods

The experimental material was collected in the southern and central municipal districts of Primorsky Krai, in Arsenievsky, Ussuriysky, Partizansky urban districts, and in the forest park zone of Vladivostok. Literature data and field studies conducted by us in 2010–2017 were used in the work. The main attention during the research was paid to the issues of silvicultural and forest taxation character. At the same time, the methods of route surveys with laying of trial plots (TP), on which the whole complex of silvicultural and taxation works was carried out, were applied.

As a methodological basis for the construction of volumetric tables, the manual by Gorsky [18] with additions and modifications resulting from the features of the stands under study [19–22] was used by us. Experimental material is presented in the number of 74 accounting trees, of which: 4 trees were felled for growth course analysis, 40 growing trees were measured with a "Tax-1" dendrometer [23, 24], and in the remaining 30, the diameter at breast height (D_{bh}) and tree height (H) were measured.

The volume of the tree trunk depends on the size (height and diameter) and on the shape of the trunk. The shape of a tree trunk in the forest is influenced by numerous factors of both internal and external environment, which are difficult and sometimes impossible to take into account in full measure. The main indicator characterizing the shape of the trunk is the runaway, which, in turn, affects its solid volume ratio.

3 Results and Discussion

Cameral processing of the initial material was started with the establishment of height classes according to the ratio of diameters at the breast height with the height of the trunks [25]. The calculation of the height grading scale was based on the generalizing curve of the relationship between heights and trunk diameters of the entire set of measured trees. This curve was calculated as the arithmetic average of height measurements for all diameter classes. Then, these data were subjected to regression analysis. According to our data, the generalizing curve of heights for Asiatic cherry trunks is expressed by the exponential-degree equation of the following form:

$$y = ax^{be^{cx}}, \tag{1}$$

where y is the generalized height (H_{gen}), m; a, b, c are the constant terms of the equation, e is the Neper number (the base of the natural logarithm), x is the argument of the equation, diameter of trees at breast height (D_{bh}), cm.

In the transcription for mathematical informatics, the generalizing curve equation for Asiatica cherry has the following parameters:

$$H_{gen} = 1.061135 * D_{bh}^{0.905282} * e^{(-0.01506 * D_{bh})} \tag{2}$$

where H_{gen} is the generalized height, m; D_{bh} is diameter at breast height (diameter class), cm.

The equation is calculated in the diameter range of 6–36 cm. The measure of the relationship is characterized by the correlation relation $\eta = 0.673 \pm 0.29$, the standard error of the equation was $\pm$ 2.6 m.

Based on the height limits, covering the entire dispersion zone, a height scale was established, including 3 discharges (Table 1). The intervals between adjacent height discharges varied modulo from 0.9 m for the lowest thickness steps and up to 1.6 m for the highest ones.

Height limits (H_{max} and H_{min}) by discharges were equated analytically, as a result of regression analysis we obtained the equations of exponential function with exponent of the following form:

$$y = ax^{be^{cx}}, \tag{3}$$

where y is height limits (H_{max} and H_{min}), m; a, b, c are the constant terms of the equation, e is the Neper number, x is the argument of the equation, diameter of trees at breast height (D_{bh}), cm.

Table 1. Scale for determining the height classes of Asiatic cherry trees.

Diameter class, cm	Height classes					
	I		II		III	
	H_{max}, m	H_{min}, m	H_{max}, m	H_{min}, m	H_{max}, m	H_{min}, m
6	6.7	5.5	5.4	4.4	4.3	3.2
8	8.2	6.8	6.7	5.6	5.5	4.3
10	9.6	8.1	8.0	6.7	6.6	5.3
12	10.8	9.2	9.1	7.7	7.6	6.2
14	11.9	10.2	10.1	8.6	8.5	7.0
16	12.9	11.2	11.1	9.4	9.3	7.8
18	13.9	12.0	11.9	10.2	10.1	8.5
20	14.7	12.8	12.7	10.9	10.8	9.1
22	15.5	13.5	13.4	11.5	11.4	9.6
24	16.2	14.1	14.0	12.1	12.0	10.1
26	16.8	14.7	14.6	12.6	12.5	10.5
28	17.4	15.3	15.2	13.1	13.0	10.8
30	17.9	15.7	15.6	13.5	13.4	11.1
32	18.4	16.2	16.1	13.9	13.8	11.4
34	18.9	16.6	16.5	14.2	–	–
36	19.2	16.9	–	–	–	–

Our investigations have shown that the correlation indices according to S. N. Svalov [26] for the equations listed in Table 2 differ insignificantly (from 0.995 to 0.997), which indicates a relatively high degree of closeness of the empirical data to the analytical data.

Parameters of equations for height discharges characterizing height limits H_{max} and H_{min} are given in Table 2.

The second stage of cameral work was to determine the volume characteristics of accounting trees. The volume of accounting trees was determined in the bark of felled trunks by the complex Huber formula, and in those measured with a dendrometer - by the complex formula of average sections. The trunk volumes obtained as a result of the

Table 2. Parameters of Eq. (3) for the limit values of the scale of elevation discharges for Asiatic cherry.

Height classes	Diameter limits, cm	Height indicators	Equation error	Equation constants		
				a	*b*	*c*
I	6–36	H_{max}	± 0.06	1.703733	0.804223	−0.01271
		H_{min}	± 0.08	1.253516	0.872889	−0.01461
II	6–34	H_{max}	± 0.10	1.210264	0.883052	−0.0148
		H_{min}	± 0.11	0.849469	0.971641	−0.01792
III	6–32	H_{max}	± 0.18	0.851164	0.963966	−0.0174
		H_{min}	± 0.22	0.468744	1.167521	−0.02674

Note H_{max} is the upper limit of height in the class, m; H_{min} is the lower limit of height in the class, m

calculations by diameter classes were equalized analytically for each elevation grade. The regression analysis showed that the best smoothing parameters had the exponent-degree function with an exponent:

$$y = ax^{be^{cx}}, \tag{4}$$

where y is the volume of trunks (V), m^3; *a*, *b*, *c* are the constant terms of the equation, *e* is a natural number, *x* is the argument of the equation, the diameter of the trees at breast height (D_{bh}), cm.

The parameters of the equations characterizing the volumes of trunks by thickness steps within the height classes are shown in Table 3.

Table 3. Equation parameters (4) of the Asiatic cherry stem volume dependence on diameter by height classes.

Height class	Diameter limits	Equation constants		
		a	*b*	*c*
I	6–36	0.000355474	2.05107723	0.012255376
II	6–34	0.000359454	1.91600825	0.018843771
III	6–32	0.000326327	1.8236639	0.022688952

The correlation indices for the equations presented in Table 2 differ insignificantly (from 0.995 to 0.998), which indicates a relatively high degree of proximity of the empirical data to the analytical ones.

In addition to the volume of Asiatic cherry trunks, the proportion of bark in percentage terms was determined by us. Bark percentage obtained as the difference of volumes in the bark and without bark, referred to the volume of the trunk in the bark. As a result of the variance analysis, it was found that there was no significant difference in the bark yield between the heights classes, and they belonged to the same general population. This conclusion with probability 0.95 is based on actual values of Student's t-test (t_{ac}), which were less than their standard value (t_{st}) for most of the thickness steps.

As a result of regression analysis, a hyperbolic function with the following form was chosen to characterize the cortex fraction:

$$y = a + b/x, \tag{5}$$

where y is the fraction of bark from the trunk volume in the bark (V), %; a, b are the constant terms of the equation, x is the argument of the equation, the diameter of the trees at breast height (D_{bh}), cm

In the interpretation of mathematical computer science, this Eq. (5) for Asian cherry has the following parameters:

$$P_b = 6.37 + 113.318/D_{bh}, \tag{6}$$

where P_b denotes bark percentage, %; D_{bh} denotes diameter classes, cm.

The similarity between the values of bark percentage calculated according to the equations and the experimental values was close enough to unity (the correlation index is 0.988).

The approximated data of trunk volumes according to the equations (Table 3) and the data on the bark share calculated according to formulas (4–6) are summarized in Table 4.

4 Conclusion

The volumetric tables for Asiatic cherry trees have been tested, which showed that the accuracy of determining the stock is within acceptable limits. So, the error in definition of a stock was ± 15%; when checked, the stock determined by the model trees was taken as a reference. The use of regression equations will greatly increase the calculation work productivity when estimating tree resources of plantations with Asiatic cherry. Volumetric tables for the three height categories could be used in forest inventory works, and be recommended for use by scientists and forestry workers in determining the resource potential and volumetric characteristics of Asiatic cherry trees in natural and artificial plantations.

Table 4. Volumes of Asiatic cherry tree trunks by height classes.

Diameter classes, cm	Height classes			Bark proportion, %
	I	II	III	
	Trunk volume, m^3			
6	0.0151	0.0125	0.0098	25
8	0.0279	0.0225	0.0174	21
10	0.045	0.036	0.027	18
12	0.067	0.053	0.040	16
14	0.095	0.074	0.055	14
16	0.128	0.099	0.074	13
18	0.166	0.128	0.096	13
20	0.212	0.163	0.121	12
22	0.264	0.203	0.151	12
24	0.323	0.249	0.185	11
26	0.390	0.302	0.224	11
28	0.466	0.361	0.268	10
30	0.550	0.428	0.318	10
32	0.643	0.503	0.375	10
34	0.746	0.586	–	10
36	0.860	–	–	10

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