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AGE FEATURES OF VARIABILITY OF TRUNK DIAMETERS IN PURE PINE STANDS

In article results of the diameters variation analysis of trunks in pine forest stands depending on age and from average diameter of planting are resulted. The increase of a trees diameters variation expressed in absolute units and reduction of variability of diameters expressed in relative units is noted. The comparative analysis of trees distributions on natural (relative) diameter classes in pine forests of Belarus is carried out. It is shown that the distribution rows received for 3–6 age classes, have no authentic differences among themselves, but authentically differ from the distribution rows received for pine forests of 1 and 2 age classes. Trees distribution rows on natural diameter classes for pine young stands (1–2 class of age), and also for forest stands of 3–6 classes of age are received.

Introduction. Foresters have been showing interest to variability of diameters in forest stands for a long time. Character of a variation of trunks diameter in the stand significantly impacts commodity composition of forest stands, which is important from the point of view of wood consumption.

Besides, the knowledge of regularities of a stands diameter composition is very useful in forest inventory. In 18 century such known researchers as V. Veyze and M. Vimenauer analyzed location of a mean tree in the range row [1, p. 200]. Later the values of diameters dividing a ranged row into separate parts, both absolute (professor Fekete), and relative (Shiffel) [2, p. 267–268] were defined.

The latter were called diameter reduction rates. Transition to relative values allowed to make the joint analysis of the forest stands significantly differing from each other in diameters. The results obtained by Shiffel concerning studying of a structure of forest stands were in details analyzed and generalized by N. V. Tretyakov [3]. He called these regularities "the unity law in stand structure".

Professor A. V. Tyurin applied another approach, allowing to study a variation of diameters in the forest stands with different tree sizes. He analyzed distributions of diameters of trees on "natural diameter class", that is the diameter classes expressed in shares of average diameter of a forest stand. Studying various plantings, A. V. Tyurin proved that nature of distribution of trees on natural classes doesn't depend on species, bonitet and completeness of a forest stand. At the same time, he found some influence of age of plantings on distribution of trees, and also very strong dependence of a diameter structure of a forest stand from intermediate fellings [4]. Tyurin summarized the data and obtained average diameter class distributions for evenly thinned out homogenous stands as a whole, and also for small-sized and the medium-sized (mean diameter less than 25 cm), large-sized (mean diameter more than 25 cm) plantings. The results of these researches were included in textbooks on forest inventory [5].

For the forests of Belarus the data of this kind are also available. They were obtained by the Belarusian Research Institute of Forestry in the process of development of commodity tables [6]. Later they became a part of Normative Materials for Forest Inventory for the Belarusian Soviet Socialist Republic, approved by the USSR State Forestry in 1982 [7]. Diameter classes in this case were called relative, but the core of the subject didn't change. The tree rows distribution by diameter were obtained not as a whole, as by professor A. V. Tyurin, but separately for each species. And the received distributions to some extent differ from each other, and it doesn't fully correspond with A. V. Tyurin's opinion that nature of distribution doesn't depend on species.

The distribution rows obtained for Belarus on relative diameter classes characterize the main forest forming species of Belarus as a whole, without reflecting age features of diameters variation. However information on these features can be very useful for stand valuation. In this regard the purpose of this article is the analysis of age features of trees diameter variation in forest stands.

Object and methods of the research. The analysis of a variation of trees diameters was carried out according to inventory of pure or with small impurity (to 2 units) pine forest stands on 790 test sites. Studied plantings represented from the 1st to the 6th age classes (Table 1).

Trees enumerations on the test sites were conducted as follows: firstly the cumulative frequencies were calculated, starting from the largest diameter classes.

Then we constructed a mathematical model of connection between diameters and the cumulative frequencies by means of interpolation technique of third-order polynomial nondecreasing sequences, which was already applied while updating forest fund using the age-class tables of classes [8].

Further by means of the received model individual diameters of trees in forest stands were calculated. The obtained diameters were grouped by natural diameter classes.

Boundaries of natural diameter classes were calculated by multiplication of mean forest stand diameter (root mean square) by the relative coefficients.

When forming the central class for the lower bound the coefficient was 0.95, and for the upper bound it was 1.05. Coefficients for a previous or following diameter class were calculated by adding or subtracting 0.1.

After determination of intervals boundaries, the calculated diameters of all trees in a forest stand were distributed by natural diameter classes. Then the received frequencies were expressed as percentage. The formed enumerations thus were grouped in age classes.

Besides, the usual enumerations by 4-centimeter diameter classes were grouped by 4-centimeter intervals of average diameter. After grouping for each diameter class, arithmetic average values of frequencies were calculated.

Average rows of number of trunks distribution as percentage by natural and absolute diameter classes were transformed so that the sum of frequencies of each row made 1000 pcs.

For every received row arithmetic mean, mean square deviation, variation coefficient, asymmetry coefficient and excess coefficient were calculated.

Table 1

Test sites distribution by age class

Age class	Quantity of test sites, pcs.
1	23
2	61
3	203
4	262
5	215
6	26
Total	790

When comparing the received rows with each other, for each compared couple of empirical distributions the zero hypothesis of their equality was made, it was checked by means of Kolmogorov-Smirnov criterion. Thus for each hypothesis the probability of commission of an error of the first sort (significance value) was calculated, this is situations when we reject a zero hypothesis in a case when it is true (there are no distinctions between distributions). The zero hypothesis was rejected only when the calculated significance value was less than 0.05. In other cases it was considered that rows of distribution have no reliable difference with each other. The Results and Discussion. The statistics of trees distribution by diameter in pine stands depending on mean diameter are given in Table 2.

According to the calculations, the mean square deviation constantly increases with average diameter increase. And this dependence is very strong. Coefficient of correlation is R = 0.996. It is quite a natural situation caused by growth of a forest stand, along with differentiation of trees by size. However the variability of diameters expressed in relative units, falls at increase of mean diameter.

The reduction of variation coefficient at increase in forest stand mean diameter confirms it. Such situation can be explained as follows: in the course of growth of a forest stand not only a process of differentiation of trees by the size occurs, but also the loss of suppressed trees lagging behind in growth, which reduces range of variation due to loss of the smallest diameter classes and positioning of an average tree closer to larger trees. With growth of a mean diameter of a forest stand distribution becomes more symmetric. The coefficient of asymmetry decreases (R = –0.929). As for excess coefficient, the link of this indicator with the mean diameter of a forest stand wasn't noticed (R = –0.571).

The statistics characterizing tree diameters distribution in pine stands by natural diameter classes according to age class is shown in Table 3.

Table 2

The statistics of trees distribution by diameter in pine stands depending on mean diameter

Mean diameter	Arithmetic mean	Mean square deviation	Variation coefficient, %	Assymetry coefficient	Excess coefficient
4	4.260	2.39	56.1	0.485	1.642
8	7.644	3.26	42.7	0.342	–0.093
12	11.472	4.22	36.8	0.373	–0.021
16	15.456	4.85	31.4	0.400	0.143
20	19.220	5.50	28.6	0.291	–0.046
24	23.148	6.27	27.1	0.251	0.086
28	27.104	6.66	24.6	0.061	–0.204
32	30.780	7.44	24.2	0.141	0.078
36	34.816	7.88	22.6	0.034	–0.157

Table 3

The statistics of row of trees distribution by natural diameter classes in pine stands

Age class	Arithmetic mean	Mean square deviation	Variation coefficient, %	Assymetry coefficient	Excess coefficient
1	0.923	0.373	40.4	0.296	–0.277
2	0.937	0.337	36.0	0.375	0.012
3	0.961	0.272	28.3	0.320	0.056
4	0.966	0.254	26.3	0.217	–0.046
5	0.969	0.246	25.4	0.172	0.013
6	0.964	0.262	27.2	0.113	–0.020

The obtained arithmetic average values for all age classes are slightly lower than one. This result can be explained this way: when forming rows of distribution by natural diameter, classes' inventory mean diameters (mean square values) were used.

As for degree of a variation of diameters expressed in relative units, it decreases with age.

Reduction both of mean square deviation and variation coefficient proves it. This tendency is rather strong. For example, for a mean square deviation the size of coefficient of correlation makes R = –0.872.

However this dependence has a little nonlinear character (Fig. 1). From 1st to the 5th age classes the variation of diameters declines, and in the 6th a definite increase in a variation of diameters is observed. As it was already mentioned above, the reduction of relative variability of data can be explained with a loss of suppressed trees from the left branch of a row that reduces range of a variation, compensating its growth at the expense of increase in the trees sizes.

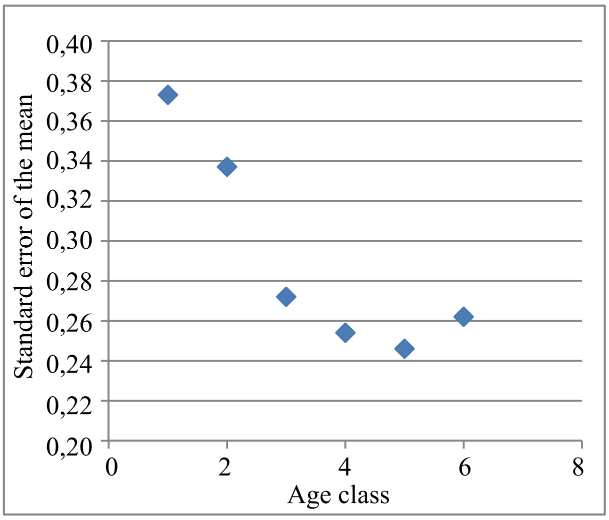

Fig. 1. Dependence of mean square deviation on age for trunks diameters in pine stands

At older age influence of random factors on loss process increases, and the role of the trees competition for environmental resources decreases. As a result, the share of the trees, disappearing from the central diameter classes, increases, and reduction of the variation range, caused by loss of the smallest diameter classes, doesn't compensate the increase in a variation caused by trees sizes growth. It causes the increase of statistics, characterizing a variation of diameters of trees in a forest stand. With course of age not only a variation decreases, but also asymmetry of diameters distribution (Fig. 2). Dependence of asymmetry coefficient value on age class is quite strong (R = –0.882). Such situation can also be caused by the situation that suppressed trees having small sizes are lost generally. This process leads to shift of distribution peak to the right, which reduces distribution asymmetry. As for excess coefficient, correlation between it and the age class is insignificant (R = 0.531).

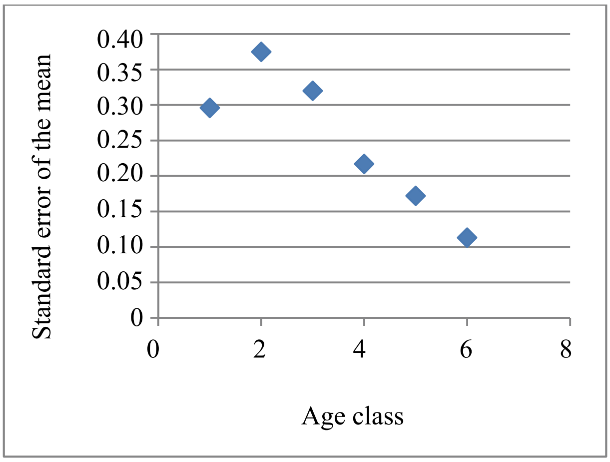

Fig. 2. Change of asymmetry of distribution of pine stand trunks diameters with age

The results of comparison of rows of trees distribution by diameters in pine forest stands for different age classes are given in Table 4. Apparently, the rows of distribution can be divided into two parts. The first group includes the distributions of trees diameters by natural diameter classes for 1st and 2nd age classes.

Table 4

Significance levels for comparison of rows of trees diameter distribution in pine stands with help of Kolmogorov-Smirnov criterion

Age class	1	2	3	4	5	6
1	1	0.097	0.000	0.000	0.000	0.000
2	0.097	1	0.002	0.000	0.000	0.000
3	0.000	0.002	1	0.913	0.370	0.859
4	0.000	0.000	0.913	1	1.000	1.000
5	0.000	0.000	0.370	1.000	1	0.913
6	0.000	0.000	0.859	1.000	0.913	1

Great values of significance levels say that there are no significant distinctions between these rows. The second group is formed by rows for the 3-6th age classes. The significance levels obtained when comparing these rows are more than 0.05. Any couple of rows belonging to different groups has significant distinctions between each other (significance levels are less than 0.05).

The results of comparison of distribution rows allow to form two common rows for each group.

The obtained rows of distribution were smoothed out by beta-function. Parameters were estimated using maximum likelihood method. For each row by means of Pearson's criterion of χ^2 the zero hypothesis was checked, it consisted in empirical distribution that follows the beta distribution law.

The hypothesis was accepted for all rows. Thus, all rows of trees diameters distribution are well described by this function. Empirical and theoretical frequencies (as percentage) of rows of diameters distribution by natural diameter classes are specified in Table 5. Variation range for distribution row received for forest stands of the 3-6th age classes is less, than for distribution row for young stock.

Table 5

Rows of trunk diameter distribution by natural diameter classes (as percentage)

Diameter class	Frequencies, %			
	1–2nd age classes		3–6th age classes bn	
	experimental	theoretical	experimental	theoretical
0.1	0.1	0.2	0	0
0.2	0.9	0.8	0	0
0.3	2.3	2.2	0.2	0.3
0.4	4.0	4.1	1.1	1.1
0.5	6.3	6.4	3.3	3.1
0.6	8.6	8.5	6.5	6.3
0.7	9.8	10.1	9.7	10.1
0.8	10.9	11.0	12.6	13.4
0.9	11.2	11.0	15.0	15.1
1.0	10.4	10.4	15.4	14.7
1.1	9.3	9.2	13.2	12.6
1.2	7.8	7.6	9.8	9.5
1.3	6.2	6.0	6.3	6.4
1.4	4.6	4.5	3.5	3.8
1.5	3.1	3.2	1.8	2.0
1.6	2.0	2.1	0.9	1.0
1.7	1.1	1.3	0.4	0.4
1.8	0.7	0.7	0.2	0.1
1.9	0.3	0.4	0.1	0.1
2.0	0.2	0.2	0	0
2.1	0.1	0.1	0	0
2.2	0.1	0.0	0	0

This fact, along with dynamics of mean square deviation and variation coefficient, testifies the tendency to reduction with age of variation ratio of tree diameters expressed in relative units.

It would be interesting to compare distribution rows for forest stands of the 1–2nd and 3–6th age classes with the distribution rows received by A. V. Tyurin and V. F. Baginsky.

The analysis of results shows that the distribution row received for forest stands of the 1-2nd age classes differs from A. V. Tyurin and V. F. Baginsky's rows. Zero values for the significance levels obtained when checking the corresponding hypotheses (Table 6). The rows of distribution received for forest stands of the 3–6th age classes, M. V. Tyurin's row for forest stands with mean diameter up to 25 cm and the row received by V. F. Baginsky, form group in which ranks have no reliable distinctions with each other.

For all zero hypotheses made about various couples of rows from this group, the probability of commission of error of the first kind exceeds level of 0.05. Absence of difference between distribution rows for the 3-6th classes of age with the distribution row by V. F. Baginsky was expected. The matter is that the last row was created according to the materials of inventory of ripening, ripe and overmature forest stands during development of commodity tables under the direction of V. F. Baginsky [6], and these forest stands are a part of the 3–6th age class. Distribution of trees by diameters in pine forest stands of Belarus corresponds to distribution row for forest stands with mean diameter less than 25 cm, obtained by A. V. Tyurin, but significantly differs from general distribution row of A. V. Tyurin, which he recommended for practical implementation, and from distribution row for plantings with mean diameter more than 25 cm. Tyurin's rows for forest stands with mean diameter less and more than 25 cm, have significant difference with each other. The general row makes intermediate value and has no significant differences with the two above mentioned rows.

Table 6

Significance levels for comparison rows of distribution by natural classes of different authors using Kolmogorov-Smirnov criterion

Distribution rows		Age classes		According to V. F. Baginsky	According to M. V. Tyurin		
		1–2-nd	3–6-th		Mean diameter less than 25 cm	Mean diameter more than 25 cm	The whole stock
	1–2-nd	1	0,000	0.000	0.000	0.000	0.000
	3–6-th	0.000	1	1.000	0.466	0.000	0.013
According to V. F. Baginsky		0.000	1.000	1	0.432	0.000	0.010
According to M. V. Tyurin	Mean diameter less than 25 cm	0.000	0.466	0.432	1	0.001	0.078
	Mean diameter more than 25 cm	0.000	0.000	0.000	0.001	1	0.573
	The whole stock	0.000	0.013	0.010	0.078	0.573	1

Conclusion. Absolute variability of diameters in forest stand increases with age, and relative variability decreases. It is caused by the fact that along with increase of tree sizes and, therefore, growth of diameters difference with a mean value in forest stand there is a process of a loss of suppressed trees, which reduces relative range of variation.

Rows of pine tree diameters distribution by natural diameter classes in young pine stands significantly differ from distribution rows of other forest stands. All rows of diameters distribution by natural diameter classes are rather well approximated by beta-function.

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