THE COMPOSITION OF SPRUCE FORESTS OF THE ARKHANGELSK REGION

Report 1

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The composition of forest stands with different wood species in different regions of the Soviet Union has been studied by many researchers, including A.V. Tyurin, A.I. Tarashkevich, N.V. Tretyakov, O.G. Kapper, I.A. Kishchenko, V.I. Levin, M.V. Davidov, I.M. Naumenko and others. At the same time, the composition of spruce forests in the Arkhangelsk Region remains poorly studied, especially owing to local forest growth conditions, even though the need for such a study has been stated repeatedly ([2], [3], [4]).

This article covers certain aspects of the composition of spruce forests.

The study was carried out on growth plots established during forest engineering work and partly by the author hereof.

The original study material (255 growth plots) was subject to thorough analysis that resulted in collection of 88 samples representing even-aged mature and over-seasoned spruce stands with a composition of 10E to 5E5 of other wood species. The choice of growth plots was based on the age of the felled model trees and normal distribution of the trees by thickness, which are typical of even-aged tree stands. Out of the 88 growth plots analysed, around 30 were established by the author.

Composition of the tree stands by diameter

Analysis of the composition of the tree stands by diameter relied on the method where the number of trees analysed was broken down by natural diameter class. Growth plots with a mean diameter of 14.0–18.0 cm composed the group of small stands, 18.1–24.0 cm – medium stands, and 24.1–32.0 cm – large stands. Within these categories, the growth plots were grouped by forest type. Midsections were found for the individual forest types and variation coefficients v and mean errors m were identified in the most populous diameter classes (0.6–1.4) of such midsections (see Table 1).

As can be seen from Table 1, the midsections of the distribution of the number of trees by natural diameter class in mature and over-seasoned spruce stands characterised by a different age distribution and different forest types but approximately the same mean diameters demonstrate a similar pattern of distribution of the number of trees by diameter (significance factors* for small, medium and large stands are well below three). Even so, this does not mean that the distribution of the number of trees by diameter is in no way related to the forest type and its age. This relationship is observed in the mean diameter of the tree stand, since in more productive forest types the stand will grow thicker over a certain period compared to the less productive types, hence the distribution pattern of the number of trees by diameter will also be slightly different.

The above conclusions helped us produce, for the purpose of practical application, three groups of distribution of the number of trees depending on the mean diameter for small, medium and large spruce stands (see Table 2).

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* Significance factors were calculated using the formula $t = \frac{M1-M2}{\sqrt{m_1^2+m_2^2}} \leq 3$, where M_1 and M_2 are arithmetic means, m_1 and m_2 – their mean errors.

Table 1

Forest type / Nmr of samples	Age of stand		Mean diameter of stand, *cm*		Statis-tical indi-cators	Natural diameter classes																Number of trees (%) thinner than average tree	
	from/to	mean	from/to	mean		0.4	0.5	0.6	0.7	0.8	0.9	1.0	1.1	1.2	1.3	1.4	1.5	1.6	1.7	1.8/2.0	1.9/2.1	from/to	mean
1. Small stands																							
Bilberry spruce forest / 10	110/170	138	13.6/18.0	16.5	*M* *v* *m*	1.3	5.4	8.4 13.9 0.37	10.5 8.2 0.27	12.2 8.4 0.32	13.2 15.2 0.63	12.2 12.7 0.52	10.5 14.4 0.48	8.3 10.0 0.26	6.2 9.5 0.19	4.6 19.4 0.28	3.3	2.1	1.1	0.5	0.2	54.3/60.5	57.1
Haircap – moss spruce forest / 6	150/253	182	13.8/17.7	16.3	*M* *v* *m*	1.2	4.9	8.3 23.7 0.80	10.3 8.7 0.26	11.8 5.0 0.24	12.3 6.3 0.31	12.0 12.2 0.62	10.6 10.8 0.47	8.6 12.8 0.46	6.6 9.6 0.26	4.9 11.9 0.24	3.5	2.1	1.3	0.9/0.2	0.4/0.1	51.3/58.6	54.8
2. Medium stands																							
Wood sorrel spruce forest / 9	101/219	135	19.6/22.6	20.9	*M* *v* *m*	0.8	4.0	8.1 13.9 0.38	11.0 12.8 0.47	13.2 15.1 0.67	13.4 9.6 0.43	13.0 14.2 0.62	11.1 11.0 0.41	9.1 20.6 0.62	6.6 10.0 0.22	4.2 23.0 0.33	2.8	1.6	0.8	0.3		55.0/60.4	57.0
Bilberry spruce forest / 42	101/230	144	18.1/23.9	20.6	*M* *v* *m*	1.0	3.5	8.4 19.3 0.25	10.9 13.7 0.23	12.8 10.6 0.21	13.5 12.3 0.26	12.9 13.2 0.26	11.4 14.1 0.25	9.0 10.1 0.14	6.7 15.7 0.16	4.6 18.5 0.13	2.6	1.5	0.8	0.3	0.1	51.9/60.6	56.3
Haircap – moss spruce forest / 4	130/198	161	19.1/20.7	19.9	*M* *v* *m*	2.5	4.9	8.9 3.9 0.17	10.9 8.1 0.44	12.4 14.0 0.87	12.0 11.5 0.69	11.3 7.8 0.44	10.8 9.0 0.45	8.8 8.2 0.36	7.0 8.3 0.29	5.0 11.8 0.30	3.1	1.8	0.9	0.4	0.1	56.2/58.6	57.3
3. Large stands																							
Wood sorrel spruce forest / 11	131/207	179	24.3/32.2	26.6	*M* *v* *m*	0.6	4.4	7.5 17.4 0.39	10.2 13.0 0.40	12.3 12.9 0.48	13.8 5.7 0.24	14.0 11.5 0.48	12.2 10.4 0.38	10.1 7.7 0.23	7.3 15.5 0.34	4.1 17.3 0.21	2.0	0.9	0.5	0.1		51.2/59.0	55.8
Bilberry spruce forest / 6	110/220	154	24.7/32.2	26.9	*M* *v* *m*	0.7	3.9	6.4 18.6 0.49	9.6 14.8 0.60	12.8 19.6 1.02	14.4 16.7 0.98	14.0 9.5 0.54	13.0 18.0 0.96	10.8 13.6 0.60	7.4 4.5 0.13	3.9 24.4 0.39	2.0	0.8	0.3			50.1/57.1	54.8

Table 2

Natural diameter classes	Number of trees, %		
	small (on 16 growth plots)	medium (on 55 growth plots)	large (on 17 growth plots)
0.4	1.2	1.1	0.6
0.5	5.2	3.6	4.2
0.6	8.4	8.4	7.1
0.7	1.05	10.9	9.9
0.8	12.0	12.9	12.5
0.9	12.9	13.4	14.1
1.0	12.1	12.8	14.0
1.1	10.5	11.2	12.5
1.2	8.4	9.0	10.4
1.3	6.3	6.7	7.3
1.4	4.7	4.6	4.0
1.5	3.4	2.7	2.0
1.6	2.1	1.5	0.9
1.7	1.2	0.8	0.4
1.8	0.6	0.3	0.1
1.9	0.3	0.1	
2.0	0.1		

The coefficients of variation of the number of trees in the most populous diameter classes (0.6–1.4) for all groups of tree stands under consideration do not exceed 20%, and they are much higher in the outermost diameter classes.

The position of an average tree in large stands (55.4±0.65%) is statistically no different from its position in medium (56.7±0.24%) and small (56.5±0.56%) tree stands.

Using these series of distribution of the number of trees by natural diameter classes in small, medium and large spruce stands of the Arkhangelsk Region, we have compiled a summary table (see Table 3) of approximate calculations offering a probability distribution (in %) of the number of trees (in the numerator) and the totals of cross-section areas (in the denominator) by diameter class, depending on the mean diameter of the stand in uniform spruce forests of the Arkhangelsk Region.

Knowing the stock volume, we can calculate the volume of each diameter class "due to the apparent proportionality between the volume and cross-section area of the elements of one plantation" [6].

Tables demonstrating the distribution of the number of trees, total values of cross-section areas and stock volumes by diameter class are of great practical value for taxation purposes, because such tables and visual taxation data can be used for an approximate distribution of the number of trees and the stock volume by diameter class, with no need for conversion.

Table 3 will produce more accurate results for the central diameter classes, and the number of trees will be less accurate for the outermost diameter classes, because the variation in the number of trees increases from the central to the outermost diameter classes.

Prof. A.V. Tyurin believes it is possible, as a way to simplify this problem for the cases most frequently observed in real life, to express the composition of tree stands by diameter through a single common series identified as the weighted average for small, medium and large tree stands [6].

Table 3

Mean diameter, cm	Diameter class, cm													Total
	8	12	16	20	24	28	32	36	40	44	48	52	56	
14	20.4/6.3	35.2/24.3	27.6/33.8	12.7/24.3	4.1/11.3									100/100
16	10.8/2.6	29.1/15.8	30.8/29.7	19.8/29.9	7.7/16.7	1.8/5.3								100/100
18	5.1/1.5	21.4/9.0	28.6/21.4	24.1/28.2	14.2/23.9	5.3/12.1	1.3/3.9							100/100
20	2.6/0.4	15.7/5.1	24.8/15.4	24.9/24.1	17.9/24.9	9.7/18.4	3.5/8.6	0.9/–						100/100
22	0.8/0.1	10.8/3.1	20.0/10.2	24.0/19.1	20.6/23.6	13.8/21.1	6.8/13.9	2.7/7.0	0.5/1.5					100/100
24	0.2/–	6.6/1.6	16.4/7.0	21.6/14.4	21.0/20.2	16.6/21.8	10.4/17.8	4.7/10.2	2.0/5.9	0.5/1.5				100/100
26		4.6/1.0	11.0/4.1	17.7/9.9	21.4/15.7	18.6/21.2	14.3/21.4	7.2/13.7	3.8/8.9	1.1/3.1	0.3/1.0			100/100
28		2.4/0.4	8.4/2.6	14.0/6.8	18.0/12.5	19.8/18.4	16.8/20.7	10.4/16.3	5.4/10.4	3.4/8.0	1.2/3.3	0.2/0.6		100/100
30		1.5/0.2	6.6/1.8	11.7/4.9	16.0/9.7	18.0/14.9	16.4/17.7	13.4/18.4	8.2/13.8	4.5/9.1	2.6/6.3	0.8/2.3	0.3/0.9	100/100
32		1.4/0.2	4.1/1.0	9.7/3.7	14.1/7.7	16.0/11.8	18.4/17.8	14.6/18.0	10.4/15.8	5.2/9.5	3.4/7.4	2.1/5.4	0.6/1.7	100/100

This weighted average series for the spruce forests of the Arkhangelsk Region with key statistical indicators is demonstrated in Table 4.

For the spruce stands of the Arkhangelsk Region, the position of the average tree is determined by the following statistical indicators: the number of trees from the thinnest tree to the average one is 56.4%, fundamental deviation σ = ±2.16; variation coefficient v = 3.8%, and mean error m = ±0.23. The variation in the number of trees in the central diameter classes (0.6–1.4) does not exceed 20%.

Table 4

Natural diameter classes	Number of trees (%) on 88 growth plots	Key statistical indicators		
		fundamental deviation	variation coefficient	mean error
0.4	1.0			
0.5	4.1			
0.6	8.2	± 1.60	19.6	±0.17
0.7	10.6			
0.8	12.6	± 1.53	12.1	± 0.16
0.9	13.4			
1.0	12.9	± 1.78	13.8	± 0.19
1.1	11.4			
1.2	9.2	± 1.17	12.7	± 0.12
1.3	6.7			
1.4	4.5	± 0.86	19.1	± 0.09
1.5	2.7			
1.6	1.5			
1.7	0.8			
1.8	0.3			
1.9	0.1			

The distribution of the number of trees by diameter class helps us identify the distribution of tree cross-section areas. After some adjustment, as recommended by Prof. A.V. Tyurin [6], we obtain the following distribution of cross-section areas by natural diameter class (see Table 5).

Table 5

Natural diameter classes	Share of cross-section areas in diameter classes, %
0.4	0.2
0.5	1.0
0.6	3.0
0.7	5.2
0.8	8.1
0.9	10.9
1.0	13.0
1.1	13.9
1.2	13.1
1.3	11.1
1.4	8.6
1.5	5.8
1.6	3.5
1.7	2.0
1.8	0.6

This series demonstrates that a tree with an average cross-section area is 34.9% away from the thinnest tree. (For pine forests of the Arkhangelsk Region – 34.8% [1]). In stands subjected to severance felling with cleared debris, the average tree is 4.04% away from the thinnest diameter class [6].

A comparison of different series of distribution of the number of trees against the series for the spruce is also of some interest (see Fig. 1).

This comparison shows a significant similarity between the series for spruce and that for pine, which brings us to the conclusion that, apart from the fact that “we should see the elements that are most uniform and suited for comparison in the dominating tiers of the plantations” [5], the uniformity is also indisputable in the plantations of natural development, without clearing the so-called debris, when we compare the series of distribution of the number of trees from different species (pine and spruce). The comparison also demonstrates the essential distinction of the spruce series from the general series of Prof. A.V. Tyurin. The reason for this deviation lies in the fact that Tyurin studied the composition of tree stands that were subject to improvement felling or where the debris was cleared.

An important aspect of the composition of tree stands is the variation of tree diameters at chest height (1.3 m), which, in case of the spruce forests of the Arkhangelsk Region, has the parameters provided in Table 6.

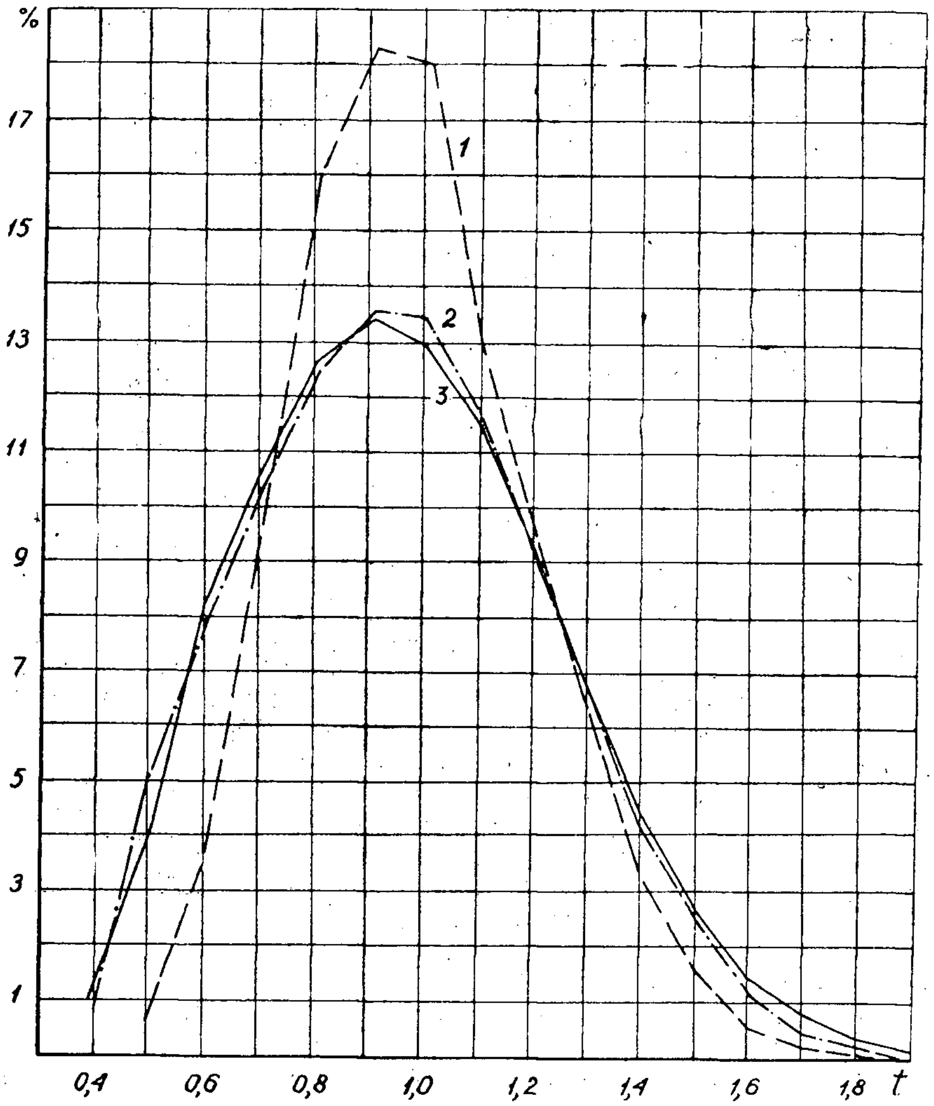

Fig. 1. Distribution of the number of trees by natural diameter class.

1 – Tyurin's general curve; 2 – Levin's curve for pine of the Arkhangelsk Region; 3 – curve for spruce based on the author's data. The horizontal axis shows natural diameter classes, and the vertical axis – the number of trees, %.

Table 6

Indicators	Unit of measurement	Forest type			
		Wood sorrel spruce forest	Bilberry spruce forest	Haircap-moss spruce forest	Average
Small stands					
Number of growth plots	ea.	–	10	6	–
Mean diameter	cm	–	16.5	16.3	16.4
Variation coefficient	%	–	31.5	32.2	31.8
Medium stands					
Number of growth plots	ea.	9	42	4	–
Mean diameter	cm	20.9	20.6	19.9	20.6
Variation coefficient	%	29.1	29.1	31.6	29.3
Large stands					
Number of growth plots	ea.	11	6	–	
Mean diameter	cm	26.6	26.9	–	26.7
Variation coefficient	%	27.5	26.4	–	27.2

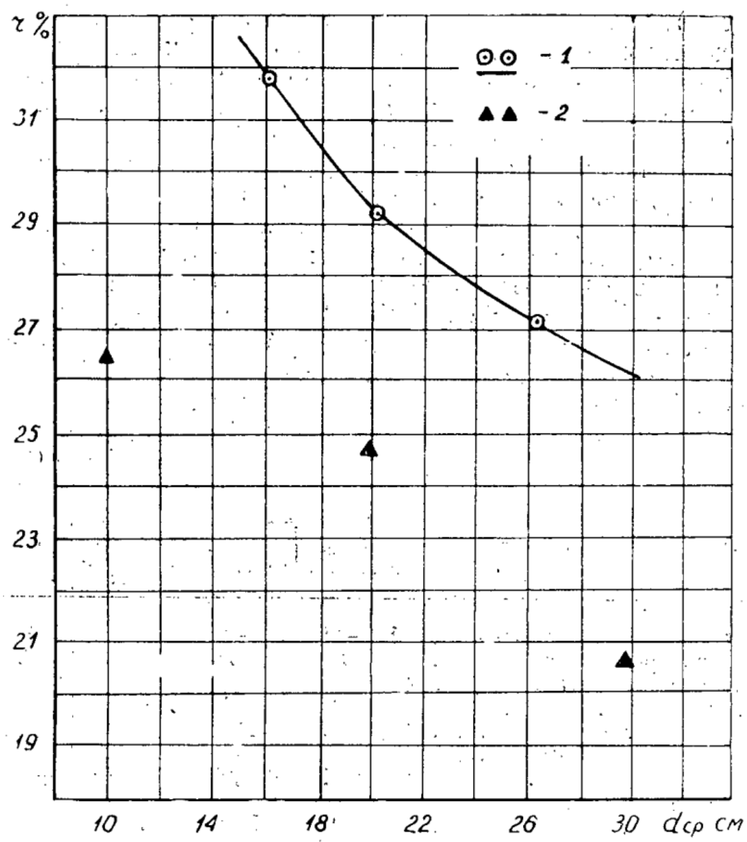

Fig. 2. Variation of tree diameter at chest height (1.3 m)
versus mean diameter of the stand.
1 – for spruce of the Arkhangelsk Region; 2 – acc. to A.V. Tyurin; r – variation coefficient, %.

The above indicates that the coefficients of tree diameter variation are similar in different forest types but if the mean diameters of these trees are equivalent. As the mean diameter increases (along with age in a certain type of forest), its variation goes down.

The average coefficient of variation of tree diameters in spruce forests of the Arkhangelsk Region is 29.3%.

Note that the coefficient of variation of diameters at chest height in tree stands of natural development is 5–7% higher than in the stands that were subject to improvement felling (see Fig. 2).

Composition of tree stands by height

An essential aspect is the relationship between the minimum and maximum height, on the one hand, and the mean height of a tree stand, on the other hand, which helps resolve many problems: during visual taxation, it enables identification of the mean height of the stand and determination of the height by diameter class, makes it easier to stratify complex stands into tiers, etc. Despite the importance of this, it is not adequately covered in the literature, specifically as applicable to taiga spruce forests of natural development.

The correlation of heights in spruce stands was studied on 86 growth plots with mature and over-seasoned tree stands (aged from 100 to 253 years) with a prevalence of spruce and with a composition of (10–5)E(5–0) of other wood species. The marginal heights of stands for each sample were obtained from the chart of heights built on the basis of model trees cut in each diameter class. The minimum and maximum heights were expressed as proportions of the mean height of stand.

We did not find any significant difference when analysing the influence of age on the marginal heights in mature and over-seasoned spruce stands. For example, our findings show that, in bilberry spruce forests aged 101–140 years, the average reduction rates are as follows: minimum

0.60 and maximum 1.21; for the age of 141–180 years, these rates are 0.59 and 1.23, respectively; and for the age of 181–240 years, they are 0.62 and 1.23. V.I. Levin came to the same conclusion when analysing the composition of pine forests of the Arkhangelsk Region [1].

The fluctuation in the heights of the stand depends to some extent on the type of forest. This statement is supported by the marginal height values we identified for different forest types (see Table 7).

Table 7

Key statistical indicators	Forest type			
	Wood sorrel spruce forest	Bilberry spruce forest	Haircap-moss spruce forest	Average for all types
Age of tree stand, years (from – to)	100–200	100–200	130–253	100–253
Number of growth plots	19	53	14	86
Minimum heights as proportion of average	0.58	0.61	0.59	0.60
Fundamental deviation σ	±0.07	±0.08	±0.06	±0.08
Variation coefficient v	12.0	13.1	10.2	13.3
Mean error m	±0.013	±0.011	±0.016	±0.009
Maximum heights as proportion of average	1.19	1.22	1.25	1.22
Fundamental deviation σ	±0.06	±0.06	±0.03	±0.07
Variation coefficient v	5.0	4.9	2.4	5.7
Mean error m	±0.014	±0.008	±0.008	±0.008
Difference in marginal heights as % of average	61	61	66	62

The type of forest has the most significant influence on the top margin of height and has almost no effect on the lower margin.

On average for the spruce stands of the Arkhangelsk Region, the minimum height is 0.60, and the maximum height is 1.22 of the mean height of stand, with a difference of 62%.

The findings of V.I. Levin demonstrate that, in pine stands, the height margins are 0.69 and 1.16 of the mean height of the stand, with a difference of 47%, which is 15% less than for spruce stands.

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