Dimensions of wood fibres and nominal specific gravity were to a great extent conditioned by heredity, while the influence of environment is very small.

Broad-sense heritability estimates for juvenile wood properties have not been published for Euramerican poplars.

Summary

In this article are described the fibre morphology and specific gravity of the juvenile wood of eight different cultivars of Euramerican poplars, planted on alluvial soil in the bottom-land of the River Danube, near Novi Sad.

The plantation was established at very narrow spacing, 2 X 2 m, in a randomised manner and with five replications. It was thinned after four growing seasons. One sample tree, i. e. a total of 40 sample trees, was chosen before thinning for each clone and each replication. The same number of sample trees was chosen also after thinning.

Fibre morphology was investigated at the age of 2, 3, 4 and 6 years. Specific gravity was tested twice, i. e. before and after thinning. The results showed that the cultivar Ostia has the longest fibres whereas the clone *'I-214'* possesses the shortest fibres. The latter is distinguished by the widest fibre with the largest lumen and the thickest walls. 'Robusta' poplar, on the contrary, has the narrowest fibres with a small diameter. Significant differences were obtained for length from the third year, for width and lumen diameter from the second year.

DUNCAN tests of fibre dimensions are presented in Figs. 1–3 and 6.

Specific density (specific gravity) decreases from 'Robust~'the heaviest, to clonee 'I-214' the lightest. The difference between these two amounts to 28 percent. Only these two clones differ significantly from the other six.

Results indicate that the dimensions of wood fibres (length: 0.42 to 0.86, breadth: 0.81 to 0.91 and lumen diameter: 0.79 to 0.89) and specific gravity (0.95) are to a very high degree controlled by heredity while the influence of environment is very small.

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The Occurrence of Forms of Norway Spruce Based on Branching Habit

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Within its natural range in Bulgaria, Norway spruce (Picea abies KARST.) shows great variation. The sources of this variation lie in the differing silvicultural conditions which occur from 900 to 2200 m. altitude leading to ecological, morphological and phenological differences.

In order to specify more exactly some of the morphological forms of spruce in the Central parts of. the Rhodopa mountains eight permanent sample plots were established each containing 200 trees at 1000, 1200, 1400, 1500, 1600, 1800, 2000 and 2150 m. above sea level.

The investigations showed that each separate form of spruce is characterized by different morphological features, made apparent by the branching. The branching is determined by the form, angle, thickness and length of the second and third order branches, and especially by the second order branches. On the basis of these external features four basic forms of spruce were recognised: comb-like, brush-like, compact and flat-branched and these are 24 transitional forms. According to the dominance of the features, the transitional forms were allotted to the four basic forms and in this way were grouped into four combined forms. Each one was characterized by its distinctive ecological, biological and silvicultural features. From this follows the need for the study of these forms as a basis for their use in selection, afforestation and management.

The following basic and intermediate forms of spruce were based on branching habits and reflect a number of important silvicultural properties. The classification shows the gradual transition from one form to another, the first name representing the dominant form.

I. Comb — Spruce:
1. Pure-comb
2. Comb to weak-brush
3. Comb to middle-brush
4. Comb to brush — Intermediate

II. Brush Spruce:
1. Brush to comb-like — Intermediate
2. Brush to middle-comb-like
3. Brush to weak-comb-like
4. Pure-brush
5. Brush to weak-compact
6. Brush to middle-compact
7. Brush to compact — Intermediate
8. Brush to weakly-flat branched
9. Brush to middle-flat branched
10. Brush to flat-branched

III. Compact Spruce:

1. Compact to brush — Intermediate
2. Compact to middle-brush
3. Compact to weak-brush
4. Pure compact
5. Compact to weakly-flat branched
6. Compact to middle-flat branched
7. Compact to flat-branched — Intermediate

IV. Flat-Branched Spruce:

1. Flat branched to brush
2. Flat branched to middle-brush
3. Flat branched to weak-brush
4. Flat branched to compact — Intermediate
5. Flat branched to middle-compact
6. Flat branched to weak-compact
7. Pure flat-branched

It is believed that the pure comb, brush, compact and flat-branched spruces are basic forms, but are found very rarely. All the rest are intermediates originating by crosses between the basic forms and later backcrosses of the first hybrid forms with the basic forms and further by crosses among themselves.

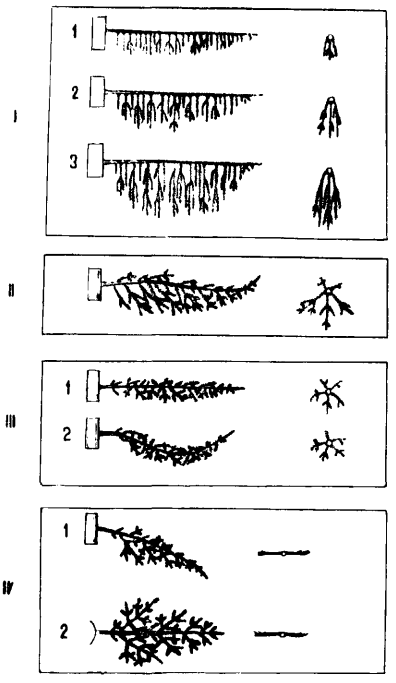

Fig. 1. — Norway spruce forms: — *(I)* Comb-spruce. — *(II)* Brush-spruce. — *(III)* Compact spruce. — *(IV)* Flat-branched spruce (fir-like spruce).

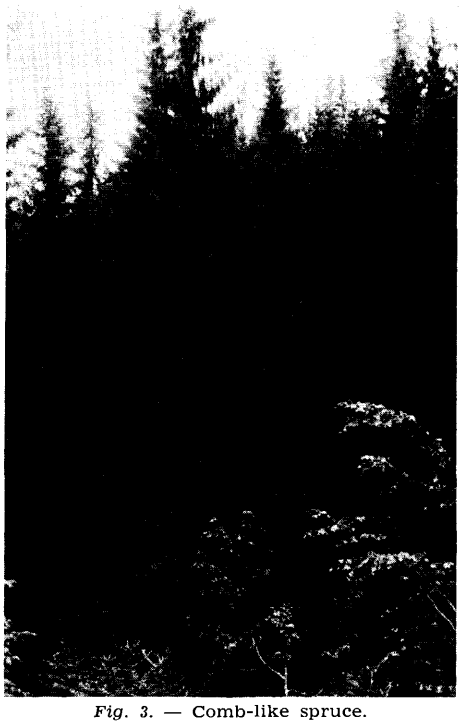

Fig. 3. — Comb-like spruce.

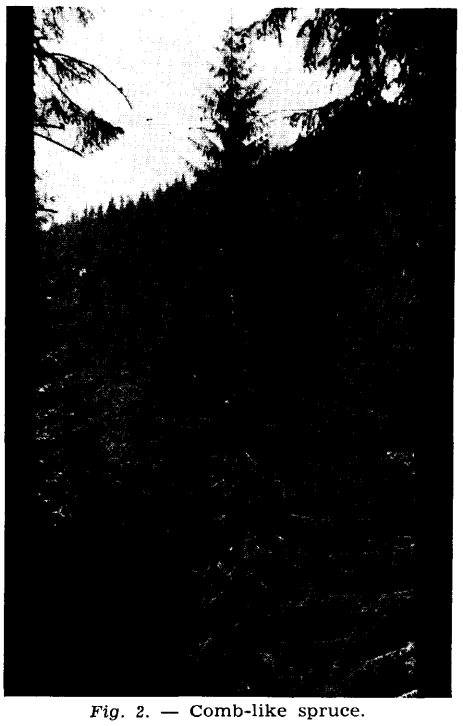

Fig. 2. — Comb-like spruce.

Fig. 4. — Brush-like spruce.

The material collected revealed that each spruce form is characterized by clearly differentiated features.

The comb spruce *(Fig. 2 and Fig. 3)* received ist name because of the structure of the second order branches, which hang down in a comb-like curtain of lengths varying from 15—20 to 130—140 cm. The first order branches are usually straight, thin, long and horizontal, making an approximate right angle with the stem. Usually they form each year of three articles on the tip, from which the second order branches are formed. After the second and third year, the long thin branches of second order, growing quickly in length and slowly in diameter, hang under their own weight and are almost never horizontal or vertical; and by their further growth form the typical comb-like appearance *(Fig. 1 — I)*. The branches vary in length and the comb spruce can be divided into short-comb *(Fig. 1 — I — 1)*, with a breadth of 15—20 cm, middle-comb *(Fig. 1 — I — 2)* with a breadth of 15—20 to 40—50 cm and long-comb *(Fig. 1 — I — 3)* with a breadth above 40—50 cm. The distance between the nodes on the stem of comb spruce is large indicating quick growth. The crown is friable (open) and when viewed from below seems well lighted inside.

The name brush spruce *(Fig. 4)* is given because of the brush-like structure of the second-order branches. The branches of the first-order are usually thin and long curved like a sword and the tips are directed upwards *(Fig. 1 — II, left)*. In youth the branches are straight and make sharp angles with the stem. The characteristic features are the branches of second order formed each year from whorls of five-articulated buds at the tips of the first-order branches. The nodes are stretched and the second order branches point in all directions. After two or three years some of the second-order branches, especially side branches, bend down under their own weight as they grow. These hanging branches of small length are similar to those of the short comb spruce, but differ considerably, because the horizontal and erect single branchlets, all form a brush-like mass *(Fig. 1 — II, right)*. The length of the internodes on the stem is long but the crown is dense and appears impenetrable from below because of the denseness of the foliage.

The compact spruce *(Fig. 5)* is similar to the brush-spruce but differs considerably in many morphological features. The first order branch in transverse profile are either horizontal or bend down *(Fig. 1 — III — left)*. Each year at the tip of the first order branches appear whorls of five buds forming branches of the second order. These remain horizontal because of their short length, considerable thickness and sturdiness to form a compact mass *(Fig. 1 — IV — right)*, uniformly embracing the branches. The crown of compact spruce is thinner than that of the brush spruce and when viewed from below appears slightly penetrable. The length of the stem internodal is smaller than that of the comb and brush forms, but larger than that of the flat-branched form.

Among compact forms a special place must be given to the "grifer" spruce *(Fig. 6 and Fig. 7)*, differing from the other forms in its shorter second-order branches, extreme looseness and moderate crown width.

The flat-branched spruce *(Fig. 8 and Fig. 9)* is the smallest has the most conical stem, *the biggest taper* and the thickest and most elastic branches when compared with the other forms. The first-order branches bend slightly downwards *(Fig. 1 — IV — left)*, making an obtuse angle with the stem and rising from the very base of the stem almost to ground level. The second-order branches arise from a two-bud node formed at the tip of the annual shoots of the first-order branches.

The second and third-order branches of typical flat-branched spruce develop in the same plane and look very much like *Abies alba (Fig. 1 — IV — right)*. The space between the nodes is very small, because of the slow growth of the shoots. This form, if met in Bulgaria is not typical and not identical with that found in Germany and Sweden where it was first described, but is probably a modification of it, distinguished by the greater bending of the second-order branches and the appearance of some compactness.

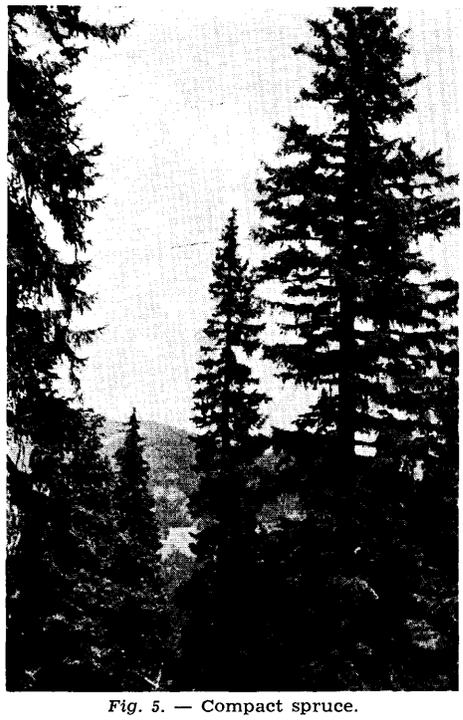

Fig. 5. — Compact spruce.

Fig. 6. — Grifer spruce.

The intermediate forms of Norway spruce which bear to a varying extent the features of the pure forms depending on the developed extent of their dominance or recessiveness link the pure forms. Their classification is often difficult, because of the great variability.

Using the phenotypic features of branching habit certain forms were not found in Central Rhodopa. Those described by G. PRIEHAUSSER 1957 in Germany the so called comb flat branched and flat branched-comb spruce, were not found in Bulgaria because the comb and flat-branched spruces are kept apart at different altitudes and represent two extreme forms.

Fig. 7. — Grifer spruce.

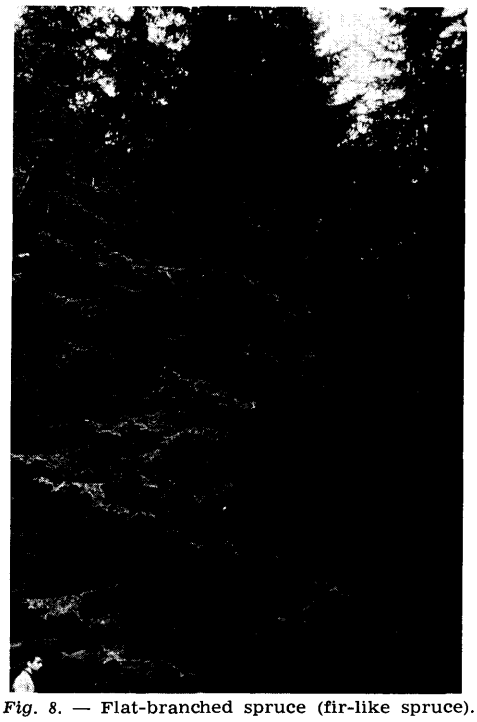

Fig. 8. — Flat-branched spruce (fir-like spruce).

The Frequency and Extent of the Forms of Spruce

In order to determine the frequency and extent of the spruce forms as defined by their branch habit, 2.000 trees were marked in sample plots and allocated to the four combined forms described above. In practice the trees were allocated to comb, brush, compact and flat branched spruces.

The data are presented in *Table 1* and *Fig. 10.* These show that the distribution and occurrence of the four forms varies with altitude.

At 1000 m a.s.l. the comb spruce constitutes 82% of the sample stands and the proportion decreases with increase of altitude to 50.3% at 1200 m, 26.3% at 1400 m, 22.3% at 1500 m, 16.8% at 1600 m, 2.2% at 1800 m, and 1.8% at 2000 m above sea level. Thus it appears that this form is best adapted to altitudes of 900 to 1000 and 1200—1300 m, and further that it is adapted to definite silvicultural conditions.

From observations on different exposures and conditions of relief it became evident that comb-spruce occurs most frequently on northern aspects on the sides of rivers, streams and valleys or other depressions where soil moisture and the atmospheric moistures are higher and meet the requirements of this form. Comb spruces with long second order branches are more often met under these conditions.

The distribution of brush spruce reveals another situation. At 1000 m above sea level brush spruce formed 18% of sample stands and the proportion rises to 74.1% at 1600 m and falls again to 9.9% at 2000 m. These data suggest some adaptation to altitudes ranging between 1200—1300 and 1800—1850 m above sea level. The wider variety of silvicultural conditions permits bigger variability in brush spruce. Usually it grows at lower temperatures in conditions of stronger sun and less soil moisture than comb spruce.

The distribution of compact spruce begins at 1400 m where it forms 1.5% of the sample stands rising to 40.2%

Fig. 9. — Flat-branched spruce (fir-like spruce).

Table 1.

Spruce forms:	Altitude above sea level in metres: 1000 Nr.	%	1200 Nr.	%	1400 Nr.	%	1500 Nr.	%	1600 Nr.	%	1800 Nr	.%	2000 Nr.	%	2150 Nr.	%
Comb-like	123	82.0	94	50.3	36	26.3	44	22.3	24	16.8	4	2.2	2	1.8	—	—
Brush-like	27	18.0	93	49.7	94	68.6	139	70.7	105	74.1	88	50.7	11	9.9	—	—
Compact	—	—	—	—	2	1.5	8	4.0	6	4.2	33	19.0	45	40.2	37	20.8
Flat-branched	—	—	—	—	5	3.6	6	3.0	7	4.9	49	28.1	54	48.1	141	79.2
	150	100	187	100	137	100	197	100	142	100	174	100	112	100	178	100

at 2000 m above sea level. Compact spruce appears to be well adapted to the lower temperatures, stronger sun light and stony soils which occur between 1850—1900 and 2100—2150 m above sea level.

Flat-branched spruce, like compact spruce, begins at 1400 m above sea level (3.6%) and its occurrence rises progressively through 4.9% at 1600 m, 28.1% at 1800 m, 48.1% at 2000 m to 79.2% at 2150 m. This points to the adaptability of flat-branched spruce to extreme climatic conditions.

The conclusion from the observations are that the intermediate forms are the most widespread. From 1000 to 1300 m the comb/brush spruces are the most numerous; from 1200—1300 up to 1500—1600 m the brush/comb spruces predominate, from 1500—1600 to 1800—1900 m brush/compact and compact/brush spruces are most frequent and from 1900 m upwards is the zone occupied by compact/flat branched and flat branched/compact spruces.

The environment evidently has exerted great influence on the origin and extent of the branch forms of spruce especially during the glaciations of the Quaternary period.

The spruces situated to the south or in the lower parts of the mountains developed in a climate permitting rapid growth and the wide internodal spaces between nodes permitted the second order branches to develop like a comb thus creating the comb-like form.

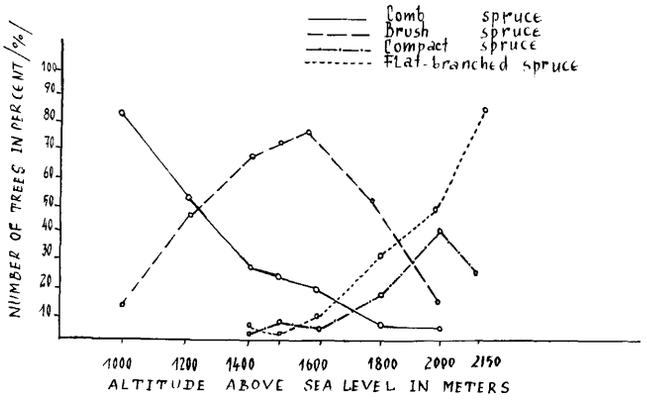

Fig. 10. — Frequency and Extent of the Forms of spruce.

The climatic factors to the north or higher in the mountains are less favourable. On these sites some of the second and third order branches of the comb spruce, having a higher water content, freeze and their function is taken by new branchlets, growing sideways and partly upwards originating from additional buds and having greater cold resistance. This is probably the way in which the brush spruce originated during the cold period, taking place now among the wide complex of comb spruce forms.

Further to the north and at higher altitudes under the influence of low temperatures and strong sunshine, the compact form has been created. The short needles and branches arranged radially expose only a small part of their surface to direct sun light and their hardiness protects them from freezing. The flexible first and second order branches give good protection against breakage under the weight of snow. In its origin this form is connected with the brush spruce and it is probable that it was created during the Glacial Period.

The flat branched spruce is situated in the northernmost regions and in the highest parts of the mountains and in some places forms the northern or upper limit to the forest. It is suggested that this is the youngest form, having its origin during the Pleistocene period. The severe climate greatly reduces its growth and the internodal lengths are minimal when compared to those of the other three forms. It is natural that in these conditions the second order branches can develop only in one plane creating flat branches which are extremely flexible.

Thus by studying the branching habit of spruce we can see their adaptation to the ecological conditions existing at different altitudes above sea level. That is why these are not only morphological but also ecological forms, because the morphology reflects the ecological conditions.

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