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Variations of Length of Vessel Members and Fibres in the Trunk of *Robinia pseudoacacia*

A. HEJNOWICZ and Z. HEJNOWICZ

Variations in the length of tracheal elements in trees with non-storeyed wood have been the subject of numerous investigations (see bibliographic lists assembled by Bisset 1949, and Spurr and Hyvarinen 1954) which lead to some conclusions of a general nature: the average length of tracheal elements increases along the radius from the centre of the tree outwards; secondly, in wood with distinct growth rings the length of fibres or tracheids within one growth ring increases markedly from the first formed early wood to late wood.

On the other hand, much less is known about the variations of element's length in storeyed wood. In fact, only one report (Chalk et al. 1955) deals with these problems. Chalk and co-workers studied the wood of subtropical tree species *(Papilionaceae, Tilliaceae)* and found seasonal changes in fibre length but no general tendency to increase the length from the pith outwards.

In non-storeyed wood the increase of fibre length away from the pith is caused by the increase of the average length of fusiform initials with the aging of cambium (Hejnowicz 1958). This of course cannot be the case in storeyed wood since, as is well known, fusiform initials of storeyed cambium do not grow in length. Nevertheless, preliminary investigations on the wood of *Robinia,* which has a typically storeyed cambium, have shown that the length of fibres of this species increases from the pith outwards similarly as in species with non-storeyed cambium. The study of this problem has been the aim of this investigation.

MATERIAL AND METHODS

The investigation was carried out on one trunk of *Robinia pseudoacacia* L. from the Arboretum of Kórnik. The age of the tree was 36 years, the height 17 m., and the diameter one metre above ground 22 cm. The length of fibres and vessel members was measured in about 700 wood samples taken from various parts of the trunk and from various parts of the particular rings. The procedure was as follows. First a groove was cut on the trunk to mark the north side and then discs about 4 cm. thick were sawn off at the levels listed in Table 1. From the northern side of each disc a narrow block was cut out from the pith to the cambium. After measuring the thickness of the annual rings the blocks were split into the particular annual growth rings. The splitting was controlled microscopically on thin transversal sections. From both faces of the rings thin shavings were removed with a razor. The shavings were macerated separately. Sections from adaxial faces were labelled *layer a,* and from the opposite faces *layer c.* Layers *a* corresponded to the earliest spring wood and layers *c* to the latest wood. The remaining part of every ring was split into two halves tangentially. Sections corresponding to the middle part of a ring were sliced off the planes of division and labelled *layer b.*

Table 1

Examined levels

Level	Heigt above ground *metres*	Length of north radius *cm.*	Number of annual rings	Number of examined rings
A	0,0	12,8	35	all, except rings 30—34
B	1,0	9,8	32	all
C	2,1	8,4	28	all, except rings 10 and 16
E	4,2	6,5	26	all
G	6,2	6,0	22	all
J	8,3	3,4	18	all
K	10,4	3,1	14	all
Ł	12,5	2,5	10	all
N	14,6	1,6	6	all
O	15,6	1,1	4	all

The first growth ring in most levels was very thin and could not be split into layers. Consequently sections from the radial side of that growth ring corresponding to its full thickness were macerated. In the case of growth rings 14—17 from level E the examinations were more detailed and for this purpose the part of the block including these rings was cut tangentially into sections 0.1 mm. thick on a microtome.

For maceration glacial acetic acid and perhydrol were used. The wood samples were placed in test tubes and a 1 : 1 mixture of the acid and perhydrol was added. The test tubes were placed in a water bath at 100°C for eight hours. After maceration the sections were washed twice with cold destilled water and then shaken in a small amount of water until they disintegrated into the particular elements. The suspension was centrifuged, the water decanted, some glycerine added, and then placed drop by drop on slides. The suspensions prepared in this manner contained almost no broken fibres.

In each wood sample the length of 50 fibres and in some samples also of 50 vessel members was measured. Measurements were made under a microscope equipped with a 7 X micrometer ocular and an 8 X objective. Alltogether about 39 000 fibres and 2 800 vessel members were measured.

RESULTS

Length of vessel members

The length of vessel members is approximately the same as the length of fusiform initials from which they developed. For this reason the length of vessel members in a growth ring is indicative of the length of cambial initials at the time the ring was formed.

Table 2

Length of vessel members (mm)

Level / No. of ring	C	E	G	J	N	O
1	0,175			0,185		0,179
2	0,178	0,177	0,169			
3			0,179		0,207	
4	0,170		0,184			0,202
6	0,187	0,197	0,178	0,197	0,204	
7			0,189			
11	0,189	0,200	0,184	0,204		
12	0,184		0,191			
16	0,184	0,195	0,188	0,195		
18			0,189	0,199		
19			0,198			
20			0,203			
21		0,210	0,209			
22	0,193		0,208			
26	0,199	0,212				

The lengths of vessel members in various growth rings from several levels are listed in Table 2. It will be seen in this table that there is a small increase of length as the distance from the pith increases. The average length of vessel members increases 10—20 per cent over a distance of about 20 rings.

Examinations of the particular layers within growth rings show that in one growth ring the length of vessel members does not vary.

Length of fibres

The first step was to determine the fibre length in different parts of a growth ring. The results are illustrated in Fig. 1. It will be seen from the figure that there is a distinct change of fibre length within one growth ring. The shortest fibres are found in the first growth layers in the part of the ring with the large vessels of early wood. In the middle part of a ring the length of fibres, having reached a maximum, remains more or less constant and drops somewhat in the outermost layers corresponding to the latest wood.

This result confirms the correctness of the sampling method used in this work. It is obvious that for disclosing the variations of fibre length along the radius

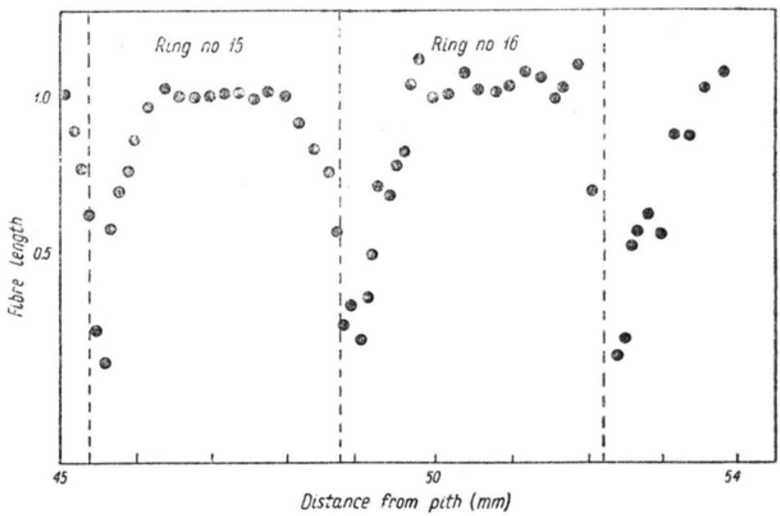

Fig. 1. Variations of fibre length in growth rings at level E

the measurements must be made in those parts of rings where the fibre length has extreme values, i.e. on both faces and in the middle of rings (layers *a, b,* and *c*).

The averages of fibre length in layers *a, b,* and *c* in successive rings on various levels are illustrated in Fig. 2. In each ring the shortest fibres occur in the layer *a* corresponding to the early wood. On the whole the length of fibres in layer *c* is somewhat less than in layer *b*. The lack of difference between these two layers in some growth rings is probably due to the fact that when slicing off the layers *c* the ring was cut in too deeply, especially in the case of thin rings.

The most characteristic trait of the variation of fibre length in *Robinia* is the distinct increase of the length from the pith outwards in layers *b* and *c*, while the length of fibres in the earliest wood remains unchanged. This trait is best illustrated

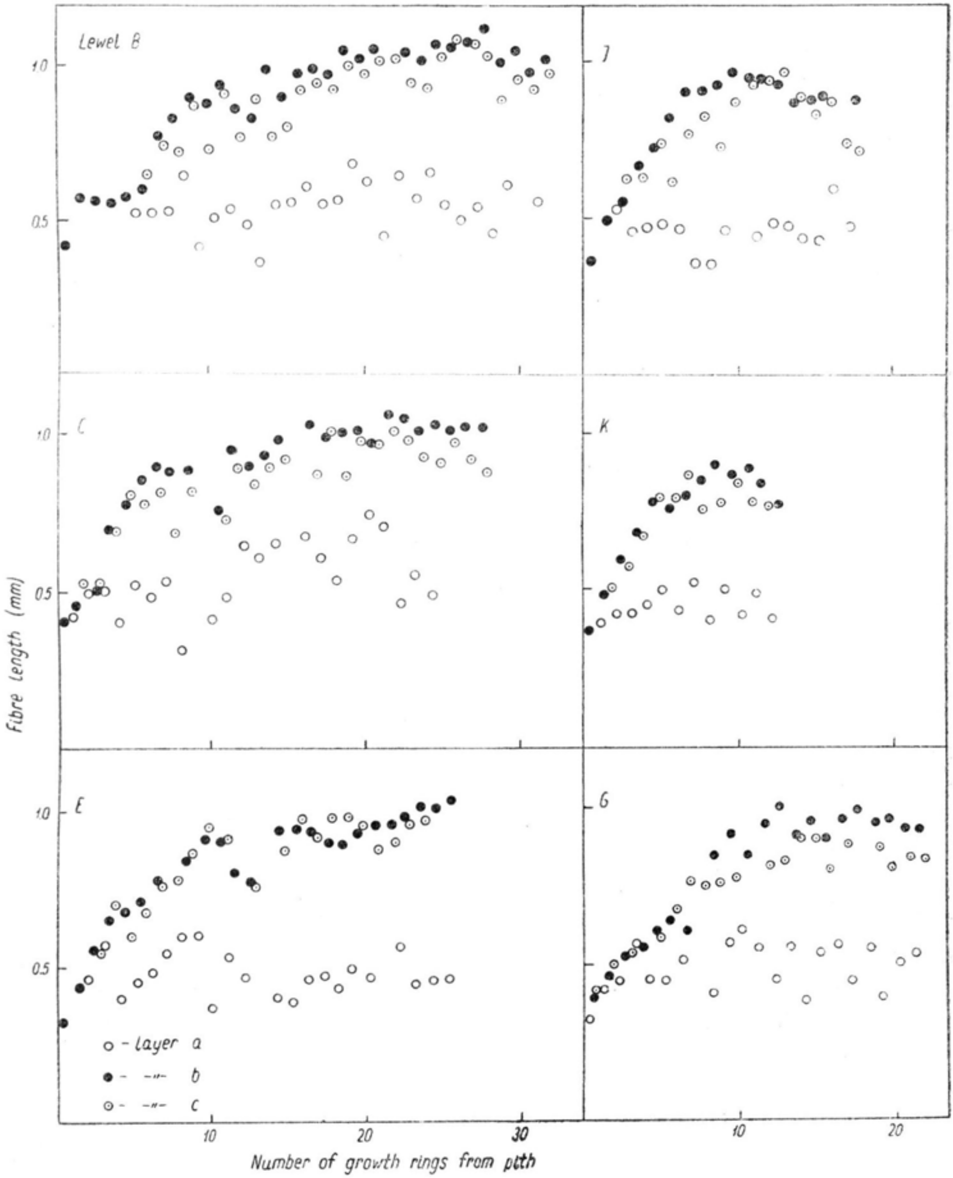

Fig. 2. Length of fibres in different layers of growth rings
Layer *a* — adaxial surface of ring (first formed earlywood), layer *b* — middle part of ring, layer *c* — outer surface of ring

in Fig. 3 showing the length of fibres in layers *a* and *b* plotted against the distance from the pith. To make the curves more legible the average fibre length from four successive rings was computed for each of the two layers and was plotted against the average distance from the pith of the particular group of layers.

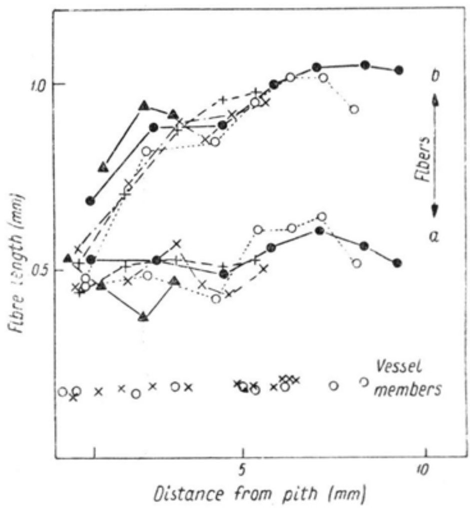

Fig. 3. Length of fibres in layers *a* (first formed early wood) and *b* (later wood) at different levels plotted against the distance from the pith. The length of vessel members from two levels is plotted (lower dots) for comparison

DISCUSSION

In species with non-storeyed cambium the increase of the fibres in length outwards from the pith is due to increasing of the average length of fusiform initials with aging of the cambium. It is indicated by the fact that the increase of vessel members length is equally pronounced as the increase of fibre length. Intrusive growth which is the other factor affecting the length of fibres, as was demonstrated in an investigation on *Populus tremula* (Hejnowicz 1957), has no influence of the increase of fibre length outwards from the pith. It is related to annual changes of fibre length only, which changes are superimposed on the increase from the pith away (Fig. 4a)

In the case of *Robinia pseudoacacia,* which is a species with storeyed cambium, the situation is different. In the wood of this species there is a small increase of the length of vessel members and a considerable increase of the fibre length in late wood (Fig. 4 b).

The small increase of the average length of vessel members in *Robinia* seems to indicate that, analogically, the length of fusiform initials increases with the aging of cambium. What is the mechanism of this growth is at present unknown. Perhaps it is caused by the elimination of the shorter fusiform cells similarly as it was observed by Bannan (1957) in non-storeyed cambium. However, the small increase of the length of fusiform initials does not explain the considerable increase of fibre length in late wood. Undoubtedly the last one is due to the higher and higher degree of intrusive growth of developing fibres. The elongation of late wood fibres (intrusive growth) is in the first years about 300 per cent and rises during 20 years to 500 per cent of the length of fusiform initials. This change of intrusive growth does not affect the fibres of the earliest wood. In this last case the degree of intrusive growth is almost independent of the age of cambium and amounts to about 250 per cent only.

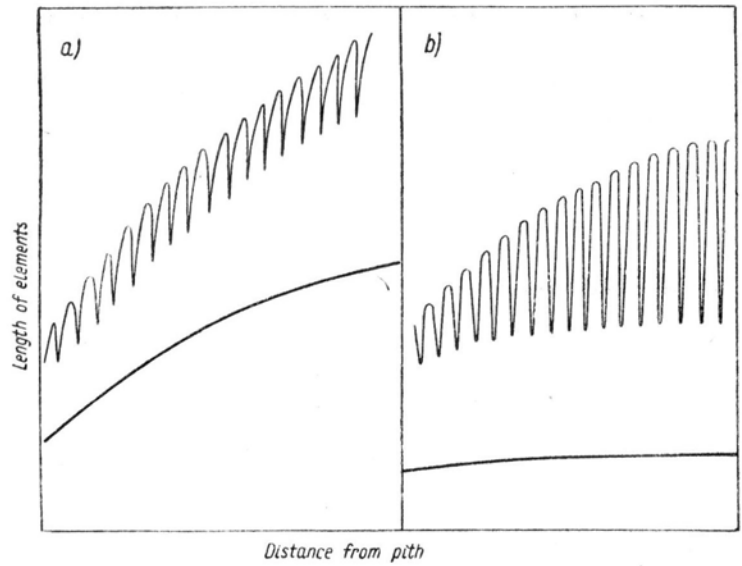

Fig. 4. Variation in length of fibres (top line) and vessel members (bottom line) plotted against distance from pith. a) — in non-storeyed wood of *Populus tremula* (Hejnowicz 1957), b) — in storeyed wood of *Robinia pseudoacacia*

Wood layers in which fibres are affected by the change of elongation constitute the main part of each growth ring and the main mass of wood in *Robinia*. Thus the length of the majority of wood fibres in *Robinia* increases from the pith outwards. This property is analogical to that manifested by non-storeyed wood, but the manner in which it develops differs in each case. In *Robinia*, representing species with storeyed wood, the increase of fibre length is due to higher and higher degree of intrusive growth whereas in species with non-storeyed cambium the increase of fibre length is due to the increase of the length of fusiform initials.

The convergence in the increase of fibre length along the radius in species with non-storeyed wood and in a species with storeyed wood seems to be not accidental.

The correlation between the length of fibres and the mechanical properties of wood is not yet clear. However, practicians are well aware that wood from the peripheral parts of a trunk has better mechanical properties than wood from the central part. The adaptive meaning of these changes is plain: wood newly formed in the trunk must have better mechanical qualities since the stresses in the trunk of a tree associated with the growth of the crown rise more rapidly than the growth of wood. The increase of fibre length away from the pith would then be one of the means for improving the mechanical strength of the trunk.

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SUMMARY

The length of fibres and vessel members in storeyed wood of *Robinia pseudoacacia* was measured.

A distinct cyclic seasonal change in fibre length, with the minimum in the first formed early wood, was recorded.

In the case of fibres of the first formed early wood there is no general tendency towards an increase of length from the pith outwards, while in other parts of wood this tendency is as clearly marked as in non-storeyed wood. Consequently the amplitude of seasonal variations of fibre length increases slightly from the pith outwards.

In non-storeyed wood the variation of fibre length from the pith outwards is associated with the changes in the length of fusiform initials. In storeyed wood *Robinia,* this variation is due to the change in degree of intrusive growth of fibres during their differentiation.

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