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Variation in length of vessel-elements and libriform fibres within one tree, *Ulmus procera* Salisb.

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ニレの1種 (*Ulmus procera*) に於ける道管細胞と繊維細胞の長さの変異

Ever since Sanio (1872) postulated the principles of variation in the length of the tracheids in the secondary wood of Scots pine (*Pinus sylvestris*), the problem of variation in length of the vertical elements of the secondary xylem attracted attention of many workers especially in recent years. In the past much work done was restricted to the study of variation in length of the tracheids in soft woods, primarily because of academic interest. More recent investigations indicated that there was a definite correlation between the length of the tracheids and certain of the mechanical and physical properties of the wood, for example, wood with longer elements possesses more tensile strength than that with shorter elements. In view of this significance the problem of variation in length of the tracheids within the bole was intensively investigated during the last five decades among some commercially important soft woods (Shepard and Bailey, 1914; Gerry, 1916; Bailey, 1920; Chalk, 1930; Priestley, 1930; Desch, 1932; Anderson, 1951; Dinwoodie, 1960).

It was considered superfluous to review the entire work on this aspect in this investigation as it was dealt with extensively by Dinwoodie (1961).

Although some work was done on the variation in length of libriform fibres and vessel-elements in angiosperms during recent years (Bisset and Dadswell, 1949; Bisset, Dadswell and Amos, 1950; Chalk, Marstrand and Walsh, 1955; Sundarasiva Rao, 1959; Swamy, Parameswaran and Govinda Rajalu, 1960; Sundarasiva Rao and Prakasa Rao, 1972), the information appears to be inadequate since the previous work was confined to only a few genera. In the present investigation an attempt has been made to

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study the problem of variation in length of the libriform fibres and vessel-elements in the secondary xylem of elm (*Ulmus procera* Salisb.). The following variations have been studied:

1. Variation in length of the libriform fibres and vessel-elements in successive growth rings from pith outwards at different levels in the bole;
2. Variation in length of libriform fibres and vessel-elements in specific growth rings at different levels in the bole and
3. Variation in length of libriform fibres and vessel-elements within one growth ring between the first and last formed wood.

Materials and Methods Material used in this work was an elm (*Ulmus procera*) collected by Dr. B. Sundarasiva Rao from Royal Holloway College, Englefield Green, Surrey, England. The approximate age of the tree was 32 years.

Four transverse discs about 3″ thick were cut from the bole at different levels (1′, 4′, 9′3″ and 13′3″) from the ground and these discs are referred to as D-I, D-II, D-III and D-IV in the work. Vessel-elements and libriform fibres from macerations were measured from every alternate growth ring from pith outwards from each one of the discs selecting from one side of the tree, namely south to avoid directional effect, if any. Macerations of the wood were done according to Jeffrey's method (1917). Variation in length of the vessel-elements and libriform fibres within one growth ring between the first formed early wood and the last formed late wood was determined in tangential longitudinal sections of 80 microns thickness from particular growth ring, that of 1953, and in portions of growth rings of 1952 and 1954. Material was selected from exact portions from specific growth ring and from late wood of the previous growth ring and the early wood of next growth ring. Lengths of fifty vessel-elements and libriform fibres were measured from each sample according to the suggestions of Chalk and Chattaway (1935) and Rendle and Clarke (1934). The average lengths of these elements were expressed in millimeters in the work.

Results Variation in cell lengths from pith outwards. The variation in length of the vessel-elements and libriform fibres of the wood in successive growth rings from pith outwards at different levels of the bole in

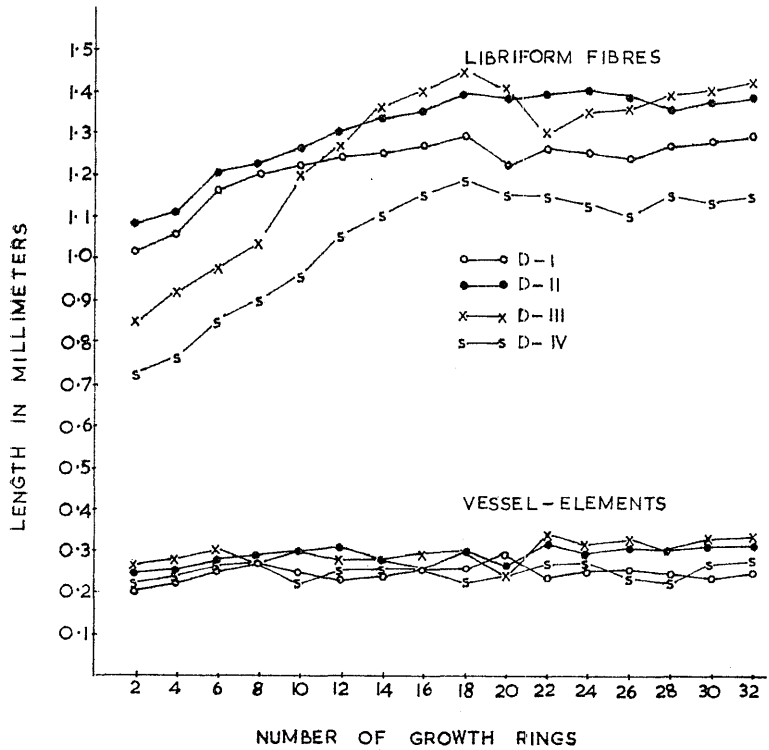

Fig. 1. *Ulmus procera*. Variation in vessel-element and fibre length in successive growth rings from pith outwards at different levels of the bole.

elm (*Ulmus procera*) was studied and the results obtained are represented in Fig. 1.

It was observed that there was rapid initial increase in the length of the libriform fibres through first 18 growth rings and thereafter the lengths of these elements showed fluctuations in the outward growth rings. On the other hand the length of the vessel-elements, although showed an overall increase, fluctuated through succesive growth rings at all the four different levels of the bole. The results obtained in the present investigation indicate that the relative increase in length varies in the different elements of the wood, for example, the increase in the vessel-elements is relatively smaller than that in the libriform fibres through successive

growth rings at any particular level. Further, it is obseved that the rate of increase in length of the elements of wood in the successive growth rings from pith is gradual at lower levels of the bole and at higher levels, for example in D-III the rise in length of the fibres is gradual through first 8 growth rings followed by a rise upto 18th growth ring and then a fall.

Observations show neither the vessel-elements nor the libriform fibres attained a constant maximum length in the latter growth rings.

Variation at different levels of the bole. Variation in the length of the libriform fibres and vessel-elements was studied in specific growth rings from base to the top of the bole. Results obtained were given in Fig. 2.

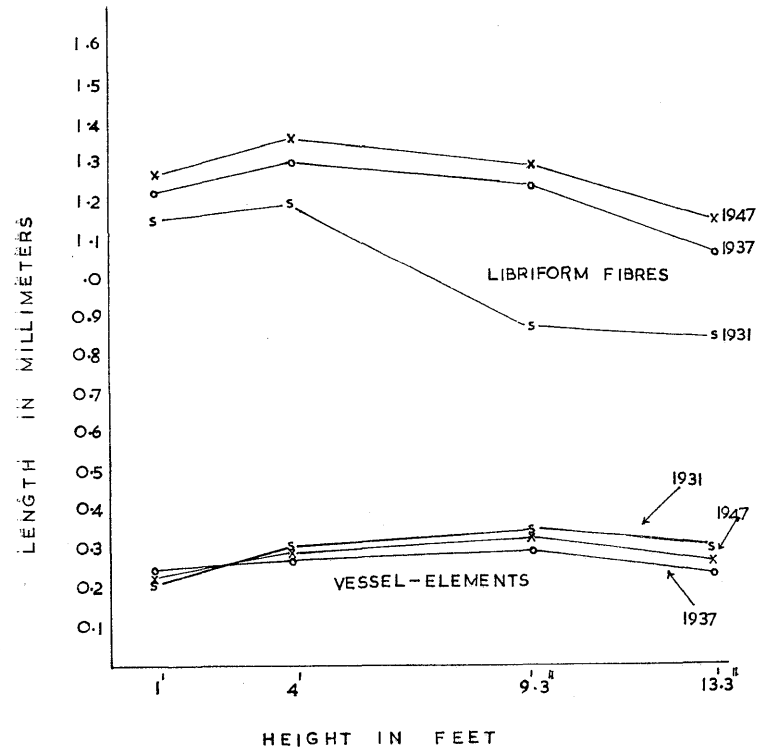

Fig. 2. *Ulmus procera*. Variation in vessel-element and fibre length in specific growth rings at different levels of the bole.

It is noted that there is an increase in the length of the libriform fibres and vessel-elements from the base of the bole upwards to a certain height after which there is a decrease towards the top of the trunk. From the observations it is obvious that the vessel-elements attained their maximum length at a height of about 9′3″ in the bole, while the libriform fibres reached their maximum at a height of about 4′ in the bole (Fig. 2.).

Variation within one growth ring. The variation in length of the libriform fibres and vessel-elements in the first formed early wood and the last formed late wood of one growth ring at a particular level, was investigated in the bole and the results obtained are shown in Fig. 3. It is observed that the vessel-elements and libriform fibres are shorter in the early wood than those of the late wood of the growth ring. From the observations it is also evident that the increase in the length of the vessel-elements and the libriform fibres is gradual from the early wood to the late wood of a growth ring. These elements appear to have reached their maximum length beyond the middle of the growth ring. There is a distinct decrease in the length of these elements in the transition from late wood of one growth ring to the early wood of the succeeding growth ring. Further the decrease in length of these elements is rather abrupt than gradual from the last formed late wood of one ring to the first formed early wood of the succeeding growth ring.

Discussion and Conclusions Results obtained in the present work on elm suggest that there is a period of rapid initial increase in length of the libriform fibres of the secondary xylem approximately in the first 18 years as compared with 20–25 years in *Carya ovata* (Pritchard and Bailey, 1916), 5–10 years in *Fagus sylvatica, Populus serotina, Betula pubescens* and *Baikisea plurijuga* (Bisset and Dadswell, 1949), 20 years in *Robinia pseudoacacia,* 15 years in *Quercus robur* and 30 years in *Acer pseudoplatanus* (Sundarasiva Rao, 1959) and about 20 years in *Terminalia tomentosa* (Sundarasiva Rao and Prakasa Rao, 1972). It was observed by Bailey (1923) that the duration of the period of rapid increase in the vertical elements of the xylem, to be longer in the conifers than in the dicotyledons. Lee and Smith (1916) record it to be 20 years in *Pinus palustris,* while Harlow (1927) states that the period of initial rapid increase to be up to 100 years in *Thuja occidentalis.* Bailey (1923) observed that this variation in length of these elements

corresponds to that of the length of the fusiform initials from which they are derived and that these initials increase in length over the first 100 years in conifers and for about 50–60 years in dicotyledons after which their length remains almost constant.

The increase in the length of the libriform fibres and vessel-elements through successive growth rings from pith outwards may possibly be attributed as stated by Bailey (1923) to the progressive increase in the length of the fusiform initials of the vascular cambium from which these elements are formed. He, further, contends that because of different frequency of the anticlinal divisions and degree of elongation of the fusiform initials, the size of these initials fluctuates in different parts of the tree in which the vascular cambium is not stratified, while, on the other hand, no change in length and configuration of these initials takes place in plants with storeyed vascular cambium.

Another point that is perspicuous from the observations in this investigation is that the rate of increase in length of the elements of wood in

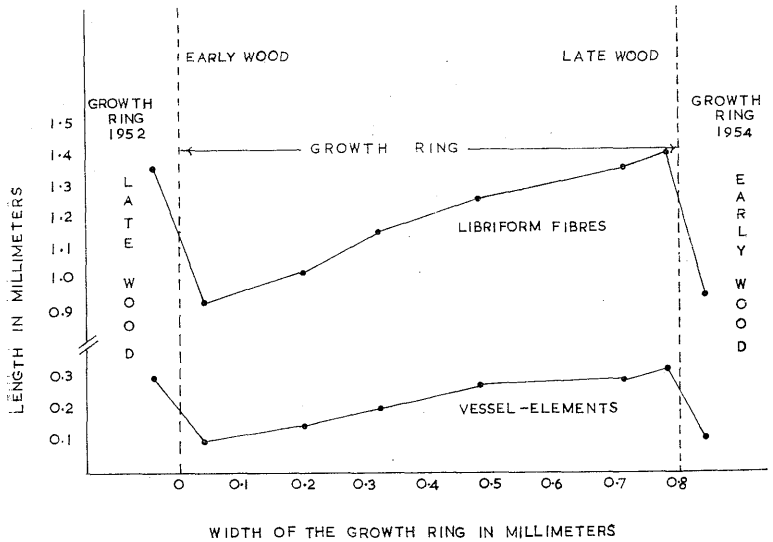

Fig. 3. *Ulmus procera.* Variation in vessel-element and fibre length within one growth ring in the bole.

successive rings from pith is more gradual in discs taken near the base of the bole than those at higher levels (Fig. 1.). It is also apparent that neither the libriform fibres nor the vessel-elements attained constant length in the latter rings. This may be due to the fact that the wood of elm, under investigation, is laid down within that period of increasing length of the cambial initials, which, as stated by Bailey (1923), may be approximately 50–60 years in the dicotyledons. Thus the type of variation in length of the libriform fibres and vessel-elements in the successive growth rings from pith outwards may be attributed to the size and activity of the fusiform initials from which these are derived.

Variation at different levels of the bole. In the present investigation it was observed that in any one growth ring the libriform fibres as well the vessel-elements increased in length from the base of the bole upwards to a maximum and then decreased towards the top of the bole. It is further noted that the libriform fibres attained their maximum length at a height of 4′. Further it was observed that the height in the bole at which the maximum length of the elements is attained varied more highly in those growth rings nearer the bark than in those nearer the pith, indicating that the length of these elements shows a high correlation to the age of the growth ring from the pith along with its position in the bole as observed by Kribs (1928) in *Pinus banksiana* and Bisset and Dadswell (1949) in *Eucalyptus regnans* and Sundarasiva Rao (1959) in oak, sycamore and robinia. Thus these two factors, age of the growth ring and its height in the tree appear to be responsible for the type of variation in specific growth rings at different levels.

Variation within one growth ring. Results obtained in respect of the variation in length of the libriform fibres and vessel-elements in the first formed early wood and the last formed late wood of a growth ring are in agreement with the type of variation noted by Bisset, Dadswell and Amos (1950), Amos, Bisset and Dadswell (1950), Sundarasiva Rao (1959) and Swamy *et al.* (1960). These elements are distinctly larger in the last formed wood of a ring than in those laid down in the first formed wood (Fig. 3.).

The proportionate increase in the length of the libriform fibres as between the early wood and the late wood of a ring may be due to a strong intrusive growth taking place at either of the ends of the derivatives of

the vascular cambium during differentiation. These fibres showed different degrees of elongation in the early and late wood of a ring in elm. In this tree there has been an increase in length of these elements to an extent of about 130 to 150%. Bisset and Dadswell (1950) reported an increase of 200% and Sundarasiva Rao (1959) observed this increase is 600–800% in robinia as against an increase of 100–300% reported by Chalk, Morstrand and Walsh (1955) for woods with storeyed cambia.

Bisset and Dadswell (1950) suggested that the length of the libriform fibres within one growth ring relates to a time factor, while Sundarasiva Rao (1959) suggested that there is not enough time for sufficient elongation of the developing elements in the early part of the season when the cambial initials divide more rapidly and vigorously. The latter is also of the opinion that more time is available for extension growth as the season progresses when cambium is less active. This appears to be a plausible explanation for the difference in length of these elements from the early and late wood of a growth ring.

It has also been observed in the present work that there is sudden fall in length of these elements from the last formed late wood of one ring to the first formed early wood of the succeeding ring confirming the observations of Bisset and Dadswell (1950), Amos, Bisset and Dadswell (1950), Chalk, Marstrand and Walsh (1955), Sundarasiva Rao (1959) and Swamy *et al.* (1960).

In conclusion it may be stated that the variation in length of the vertical elements of secondary xylem from pith outwards along one radius is associated with the activity of the same fusiform initials throughout. Variation in a specific ring at different levels in the bole, on the other hand, is associated with the different fusiform initials which have been formed over a long period in the life of the tree. Variation within one growth ring may be due to the activity and seasonal flow of hormones following the opening of the buds and the resumption of the apical growth as well as to the environmental factors affecting the development and differentiation of the elements of the wood.

Summary

Variation in length of vessel-elements and libriform fibres was studied

in *Ulmus procera* Salisb. It was observed that 1) the libriform fibres and vessel-elements increased in length at first rapidly and afterwards slowly at any one level in the bole from the pith outwards in successive growth rings, 2) the increase in length of these elements is more gradual through successive growth rings from the pith at the base of the bole than that at higher levels, 3) in any one growth ring the length of these elements increased from the base of the bole upwards to a certain height and then decreased towards the top, 4) the position in the bole, where the maximum length of these elements was attained, is highest in those rings farther the pith and 5) the libriform fibres and vessel-elements are distinctly longer in the last formed late wood than those of the first formed early wood within a growth ring.

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Ulmus procera の材の導管細胞と繊維細胞の長さの変異を研究した。導管・繊維細胞の長さは内側から外側の年輪に移行するにつれ，はじめは急速に，後にはゆるやかに増加する。同一年輪の中では春材初期のものが最も短く，秋材後期のものが最も長い。