BIORESEARCH BULLETIN
Sapience Research Labs

ORIGINAL PAPER OPEN ACCESS

Vascular cambial activity in *Populus nigra* L. from temperate climate of Kashmir Himalaya

Bilal Ahmad Wani and Amina Khan

Abstract

Vascular Cambium, a meristem responsible for the formation of wood by way of growth and divisions of its components i.e. ray and fusiform initials were analyzed during different months over two consecutive years in order to assess their impact on growth in *Populus nigra* from temperate climate of Kashmir Himalaya. The maximum and minimum dimensions of fusiform initials and ray initials were in winter and summer seasons respectively while the horizontal and vertical diameters of ray initials were maximum and minimum in summer and winter seasons respectively.

Key words: Vascular cambium, Fusiform initial, Ray initial, *Populus nigra.*

Bilal Ahmad Wani and
Centre of Research for Development,
University of Kashmir, Hazratbal
Srinagar – 190006 (India).
Amina Khan
Department of Botany,
University of Kashmir, Hazratbal,
Srinagar –190006 (India).
Corresponding Author Email :- arfee.b@rediffmail.com.

Web address:
http://bioresonline.org/archives/A158.pdf

Article citation:
Bilal Ahmad Wani and Amina Khan. 2011. Vascular cambial activity in *Populus nigra* L. from temperate climate of Kashmir Himalaya. Bioresearch Bulletin 2: 135-144.

INTRODUCTION

Woody trees possess a power of secondary growth by virtue of which, they increase in girth. This activity of secondary growth results in the formation of wood which, by nature is secondary xylem constituting vessels, fibers, rays, parenchyma etc. All these structures are formed by a mersitem called vascular cambium which, is made up of two types of cells, called as fusiform and ray initials. The fusiform initials give rise to vertically oriented structures while ray initials give rise to horizontally oriented structures.

Number of worker have studied the vascular cambium of trees (Dave and Rao, 1982; Ghouse and Iqbal 1975, 1977; Ghouse et al., 1980; Han and Woong, 1993; Iqbal 1990; Khan et al., 1988; Khan, 2001; Paliwal and Yadav, 1999; Paliwal et al., 2002; Rao and Rajput, 1999; Rao et al., 1996) in different trees, but littile is known about the activity of vascular cambium of *Populus nigra* growing under the temperate climate of Kashmir Himalaya. Keeping in view the above fact, an attempt was made to assess the activity of vascular cambium of *Populus nigra*, as its wood is suitable for veener, pulp, plywood, laminated wood, reconstituted wood products, artificial limbs, fruit boxes, agriculture implements, furniture, tool handles and sports goods like cricket bats etc.

METHODOLOGY

Kashmir, administratively one of the provinces of the Jammu and Kashmir State, is situated on the northernmost edge of India. The Valley of Kashmir, a great elliptical bowl, extends from 33^{o}20¢ to 34^{o}54¢ N latitudes and 73^{o}55¢ to 75^{o}35¢ E longitudes. It extends roughly 187 km in length and about 116 km in breadth along the latitudes of Srinagar. The Vale covers an area of 15,948sq.km.

The territories forming Kashmir cover a wide area, mostly mountains with an outer fringe of alluvial plains bordering the outer hill region to the south. The entire territories of the Kashmir Valley form two distinct topographic divisions, the mountain ranges and the Valley proper.

With lofty, snow-covered Himalayan Mountains girdling the Valley, its altitude ranges from 1,600m (Srinagar) to 5,420m (Kolahoi). Kashmir falls in the lesser Himalayan zone of the great Himalayas. The Himalayan ranges play the major and pivotal role in determining the climate of the Kashmir valley. The southern flank of the Pir Panjal Mountains certainly acts as an effective barrier to the summer monsoon, the bearer of moisture in the sub-continent. The summer rainfall of the valley clearly reflects this shadow effect. However, the Greater Himalayas exercise little obstruction influence on the influx of the westerly troughs, which frequent the Valley from the west and the northwest during winter.

On an average, the climate of the Valley is sub-Mediterranean, with bixeric regimes, having two dry spells in June and September, and high precipitation during the cool season. The Kashmir Valley enjoys an enchanting climate for the major part of the year. It has continental climate, marked by four well-defined seasons a year. (1) winter (December– February), (2) spring (March–May), (3) summer (June-August) and (4) September - November). the data on the climatic factors were collected from the meterological department Rambagh Srinagar government of India.

The geographical location along with other characteristics of the selected site and material are summarised in **Table 1.**

Cambial Characteristics

Field Work

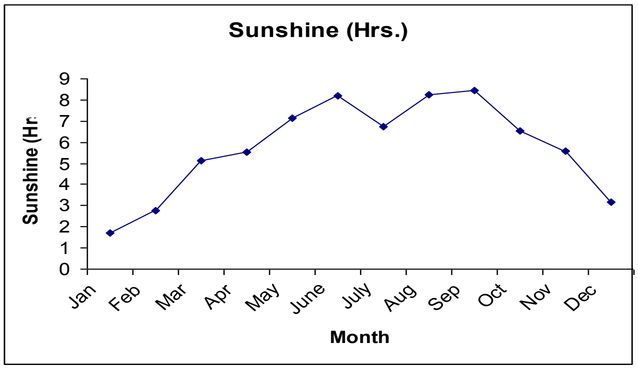
To study the cambial characteristics (i.e. cambial activity in relation to season, twelve trees of *Populus nigra* L., were selected from the natural habitats. Periodical monthly observations of cambial activity were made during two consecutive years (2005 and 2006). Cubical samples 2x2x2 cm comprising tissues along with outer bark and inner sapwood were chiselled out at breast height (1.3 m) from selected trees. Two trees were used on each occasion and no samples were collected from the same tree within three months. The samples were fixed in formalin Aceto-alcohol (F.A.A.) (Johansen 1940). After three days the material was transferred to 70% ethyl alcohol for preservation.

Laboratory Work

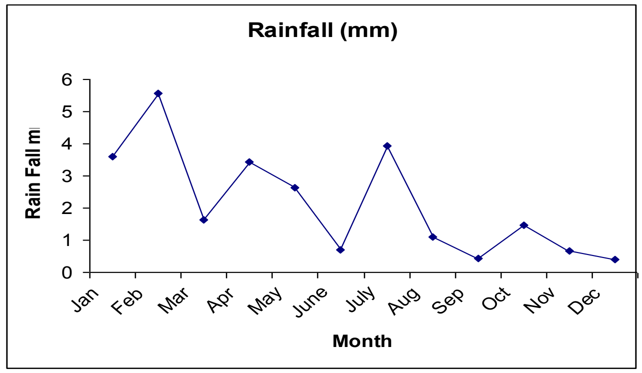
To assess the cambial activity 10-15 mm thick tangential longitudinal sections were cut with Reichert sliding microtome and also manually with the help of sharp razor.

Table 1:

Factor	**Site (Khrew)**
North Latitude	30º 12′
East Longitude	75º 35′
Elevation (m)	2000
Soil	Sandy clay
Age in years	10- 13



Graph 1: Sunshine Hours during different months of Year



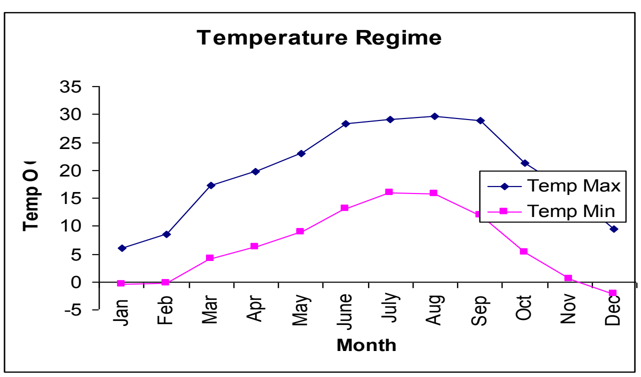
Graph 3: Rainfall during the different months of year in mm

Staining procedure

For staining the section Foster (1934) and cheadle (1953) method was followed. The section were first put in 1% Tannic acid for 5-10 minutes and then washed 3-5 times with distilled water. After washing with distilled water, sections were transferred to ferric chloride for 5-10 minutes. Again sections were washed with distilled waster 3 to 5 times. After that the section were transferred to sodium bicarbonate solution for 30 minutes, then sections were put in Lacomoid blue for 12 to 18 hours and after then washed with sodium hydrogen carbonate for few seconds. Now sections were transferred to clove oil for 10-15 minutes. After that they were transferred to different grades of alcohol and finally to Xylene in order to achieve complete dehydration and finally mounted on glass slides with Diphenyl Pthalte Xylene (DPX) as mountant.

Microscopy

To determine cell size, micrometry was done. The stages and Ocular micrometers were calibrated. A minimum of 100 randomly selected elements per block of each species were measured. The cell size was determined for each month after pooling all readings taken from relevant samples obtained during the two collection years as per Siddiqui (1991). The relative proportion of fusiform and ray initials was determined from Camera lucida drawings as per Ghouse and Yunus (1973). The ray height was classified into different categories viz. short (up to 300 mm) medium (301-600 mm) and tall 601 mm onwards), while these of varying width as uni-bi-tri and multiseriate.



Graph 2: Minimum and Maximum temperature during the different months of year

Statistical analysis

The data collected for present study was statistically analyzed by using Sigma Plot 12.0 statistical software (SPSS. Chicago. IL.USA) and Minitab 11.0 for windows.

RESULTS

Populus nigra L.

The vascular cambium of *Populus nigra* consists of two types of initials. Of these two types of initials one is comprised of spindle shaped cells called as fusiform initials. The other being almost iso-diametric to rectangular in shape, called as ray initials. The tapering ends of vertically aligned fusiform initials overlap one another irregularly rendering the cambium non-storied or non-stratified in structure. The cambial initials vary in dimensions with changing climatic conditions. Fusiform initial walls exhibit primary pit fields which become particularly prominent during the dormant phase of the cambium.

The average length and width of fusiform initials vary from 436 µm (June) to 512 (January) and 18 µm (September) to 22 µm in (February) respectively. On whole the initials are shorter during winter than during the rest period of the year. (**Table 2**) The average vertical and horizontal diameters of ray initials vary from 31-37 µm and 25 -32 µm respectively. The fusiform initials divide pseudo transversely resulting into two initials (**Fig 1 A, B**). The ray initials also divide to increase their number. All this happens in order to cope with the expansion of the stem axis. New ray initials are also added by conversion of fusiform initials into ray initials through transverse, terminal or lateral segmentation. Depending upon the cambial makeup, the fusiform and ray initials in a tangential plane constituted 72 percent and 28 percent respectively. On the basis of height the cambial rays classified into three groups viz., short (300 µm or below), medium (301-600 µm) and tall (above 601 µm). The rays of different height and width occur but tall cambial rays were predominating over the others with average height and width of 731 and 69 µm respectively.

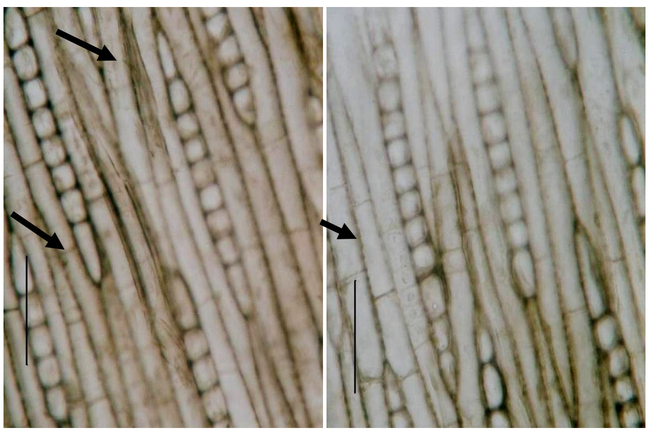


Fig1: A **Fig: B**

A: T.L.S. of *Populus nigra* showing uniseriate cambial rays and septate fusiform Initials

B: T.L.S. of cambium of *Populus nigra* showing dormant fusiform initials with beaded appearance on radial walls.

Scale bar = 40 µm for A, B

DISCUSSION

It was Grew (1682) who first introduced the term cambium and later Sanio (1863) stated that it is lateral meristem. It was De Bary (1884) who give the modern concept that it is a single layer of initials. Later the concept of cambial zone has been extended in order to incorporate undifferentiated derivatives in addition to the true initials. The same concept has been followed by Cockerham (1930), Artschwager (1950), Newman (1956), Kozlowski (1971), Ghouse and Iqbal (1975), Iqbal (1990), Fahn (1997), Paliwal and Yadav (1999) and Paliwal et al., (2002).

The basic composition of vascular cambium is elongated fusiform initials and roughly isodiametric ray initials. Bailey (1923) has recognized two basic patterns of cambial structure storied or stratified and non storied or non stratified. In former the fusiform initials occur in horizontal tiers with end of cells appearing approximately at the same level in a given tier, and in the latter the end walls of the adjacent initials overlap to a considerable extent. Bailey (1923) stated the stratified type of cambium is phylogenetically advanced. Similar opinions were given by Metcalfe and Chalk (1950), Barghoom (1964), Fahn (1974), Esau (1977), Iqbal (1979), Khan (1980), Siddiqui (1983), Ajmal (1985), Kafeel (1986), Khan (2001), Mahmood (2001). In the presently investigated species of *Salix alba*, arrangement of cambial initials depicts a clear non-stratified structure. The non stratified structure of the cambium has been reported earlier by Khan (1977), Iqbal (1979), Khan (1980), Siddiqui (1983), Ajmal (1985), Kafeel (1986), Khan (2001), Khan et al., (2005), Khan and Siddiqui (2007a), Venugopal and Liangkuwang (2007) and Wani and Khan (2008,2009).

Bailey (1923) while working on wide variety of temperate and tropical tees and concluded that cambial initials vary in length in non- stratified type from 460-4400 µm and are generally short in stratified type of cambium. The observations regarding this aspect indicate that in the present investigated species of *Populus nigra*, the mean length of fusiform initials vary from 436- 512 µm , thus goes in agreement with result of Bailey (1923) but contradicts with some of workers like Ghouse and Iqbal(1975), Ghouse et al ., (1980), Khan (1980), Cumbie (1983), Khan (2001), Mahmood (2001),Khan and Siddiqui (2007c) who have found fusiform initials length fall shorter than Bailey's reported limit for non-stratified cambium.

The anatomical variations which the cambium experiences during different seasons of the year have been analyzed by a number of workers like Eames and MacDaniels (1947), Esau (1965), Srivastava and O'brien (1966), Robards and Kidwai (1969), Murmanis (1970,71),Khan (1977), Iqbal (1979), Khan (1980), Siddiqui (1983), Kafeel (1986), Rao and Dave (1986), Venugopal and Krishnamurthy (1989), Antonova (1996), Antonova and Stasova (1997), Khan (2001), Mahmood (2001), Rensing and Samuel (2004) and Venugopal and Liangkuwang (2007). The radial walls of the fusiform initials have been reported to be usually

Table 2: Dimensions of fusiform and ray initials in (µm) *Populus nigra* during different months of year

Months	Length of fusiform initials	Width of fusiform initials	Vertical diameter of ray initials	Horizontal diameter of ray initials
January	512	22	29	27
February	510	22	28	26
March	494	21	29	26
April	475	20	32	29
May	455	20	34	30
June	436	19	35	31
July	438	20	32	30
August	460	19	31	28
September	477	18	28	29
October	490	19	29	27
November	503	20	30	26
December	510	21	28	29
LSD ($P \leq 0.05$)	64.12	1.21	0.72	1.16
($P \leq 0.01$)	87.16	1.65	0.98	1.58

thicker than the tangential walls, especially during dormancy and the primary pit fields appear deeply depressed in tangential longitudinal view giving a beaded appearance to the radial walls. Similar observations have been made in the present investigated species.

Cambial initials periodically undergo anticlinal and periclinal divisions Bailey (1923), Eames and MacDaniels (1947), Bannan (1956), Rao and Dave (1986), Han and Woong (1991), Fahn (1997), Mahmood (2001), Khan (2001) and Esau (2002). The anticlinal divisions add to the cambial population while the periclinal ones increase the number of cambial derivatives emanating new phloem and xylem elements. Two fundamental types of anticlinal divisions have been recognized by Bailey (1923) in the cambium of vascular plants. In one type, the anticlinal division occurs in a radial longitudinal plane and in the other pseudo- transverse wall formation takes place running a skew intersecting the two radial walls at two different levels Philipson et al., (1971), Khan (1980), Khan and Siddiqui (1980), Zargoska-Marek (1984), Khan et al.,(1988), Iqbal (1990), Han and Woong (1991), Venugopal and Krishnamurthy (1989), Khan (2001) and Mahmood (2001). In the present study only pseudo- transverse type of division were found as non stratified type of cambium structure were present. The anticlinal divisions in the cambium have been noted to be pseudotransverse, as it has been found in the majority of forms having non- stratified cambium (Bailey, 1923; Esau, 1965; Fahn, 1974; Iqbal, 1990; & Khan, 2001). The pseudotransverse wall formation observed in the present study varies in length from short to long. Sometimes the dividing wall almost extending from one end of the cell to the other , as it has been reported by Khan (1977), Iqbal (1979), Khan (1980) and Siddiqui (1983).

Barghoorn (1940 a, b; 1941 a, b) and Braun (1955) carried out detailed work on ray initials in conifer and dicotyledons, while developmental studies were worked by Bannan (1950, 1951,1953,1956); Evert (1959,1961); Cumbie (1963,1969 a,b); Ghouse and Yunus (1973); Ghouse and Iqbal (1977); Khan(1980); Khan et al., (1983); Siddiqui (1983); Ajmal (1985); Kafeel (1986); Ajmal and Iqbal (1987); Khan (2001); Mahmood (2001).Earlier works on ray initial formation indicate that the ray initials may originate in more than one way. Sometimes, they arise as a single cell which may be cut ends of fusiform initials as terminal segments (Bannan.1951, 1956; Braun 1955; Khan, 1980; Siddiqui,1983). They may also arise either by transverse fragmentation of fusiform initials (Whalley, 1950; Bannan, 1951; Srivastava, 1996; Khan, 1980; Siddiqui,1983; Mahmood, 2001; Khan,2001) or a declining fusiform initial may reduce to a single ray initial (Barghoorn,1940, 1941a ; Fahn, 1982).

As for as the presently investigated species is concerned , it show the first two types of ray formation .After their development .they continue to increase in number to a considerable extent mainly through multiplication of the existing initials as has been reported by (Barghoorn, 1941a,b; Braun, 1955; Evert, 1961, 1963a; Ghouse and Yunus, 1973; Khan, 1977; Khan,1980; Khan et al.,1983, Mahmood, 2001; Khan, 2001). In the presently investigated species, rays also showed increase in width and height by fusion of two or more vertically and radially aligned rays. Such fusions result from intervening fusiform initials or by multiplication of already existing ray initials of the adjacent panel of rays (Barghoorn, 1941b; Philipson et al., 1971; Bartwal et al., 1983; Khan et al., 1983; Rao, 1988). Splitting of rays also occurs as a result of intrusive growth of fusiform initials in all the species investigated as it has been reported by Khan (1980) in C. citrinus, *E. maculata and E. jambolana* and Khan et al., (1983) in *C. sinensis*. Earlier workers have also recorded similar observations in various species (Barghoorn, 1940a, b; Esau, 1965; Evert, 1961; Cheadle and Esau, 1964; Khan 1977; Bartwal et al., 1983 Siddiqui 1983; Iqbal 1990; Khan, 2001; Esau, 2002).

Bailey (1923) while studying the structure of *Pinus strobus* reported that the fusiform initials constitute about 87.5% of the total area of the cambial zone. Wilson (1963) calculated the surface area of the cambial zone of *Abies concolor* and found that the fusiform cells constitute more than 90% by volume of the cambium and its derivatives. Similarly, Kozlowski (1971), Butterfield (1972), Margaris and Papadogianni (1977), Ghouse and Jamal (1979); Ajmal (1985) and Kafeel, 1986 had also recorded similar high percentage of fusiform initials .In the present study the fusiform initials constitute 72% in Salix alba, of the tangential area of the cambial cylinder which is much lower as compared to that of Bailey (1923) and Wilson (1963) observations, but are almost in accordance with the workers like Ghouse and Yunus (1973,1974a,b), Khan (1977), Khan and siddiqui (1980, 1983), Venugopal and Krishnamurthy (1989), Mahmood (2001), Khan (2001), Khan et al., (2005), Khan et al., (2007), Khan and Siddiqui (2007a,b) and Wani and khan (2008, 2009, 2010).

REFERENCES

Ajmal S. 1985. Studies on vascular cambium and its derivatives in some arborescent Moraceae. Ph.D. Thesis, A.M.U. Aligarh India.

Ajmal S and Iqbal M. 1987. Annual rhythm of cambial activity in *Strebulus asper .IAWA bulletin n.s* 8:275-283.

Anonymous. 2001. District wise area and production of main fruits in J and K; Department of Horticulture J and K Government official document.

Antonova GF and Stasova VV. 1997. Effect of environmental factors on wood formation in larch (*Larix sibica* Ldb.) stems. *Trees* 11:462-468.

Antonova GF. 1996. Participation of xyloglucan in the growth of conifers tracheid. In: proceedings international conference "*Ecological and physiological aspect of xylogenesis in conifers*" 6-9 August, Krasnoyarks, Russia. 4-8.

Artschwager E. 1950. The time factor in the differentiation of the secondary xylem and phloem in pecan. *Am. J. Bot*. 37:15-24.

Bailey IW. 1923. The cambium and its derivative tissue. IV. The increase in girth of cambium. *Am. J. Bot.* 10:499-509.

Bannan MW. 1950. The frequency of anticlinal divisions in fusiform cambial cells of *chamaecyparis*. *Am. J. Bot*. 37:511-519.

Bannan MW. 1951. The cycle of size change in the fusiform cambial cells in *Thuja occidentalis* L. *Can. J. Bot*. 31:63-74.

Bannan MW. 1953. Further observation on the reduction of fusiform cambial cells in *Thuja occidentalis* L. *C. J. Bot*. 31:63-74.

Bannan MW. 1956. Some aspects of the elongation of fusiform cambial cells in *Thuja occidentalis* L. *Can .J. Bot*. 34:175-196.

Barghoorn ES Jr. 1940a. Origin and development of the uniseriate ray in the coniferae. *Bull. Torrey Bot. Club*.67:303-328.

Barghoorn ES. 1940b. The ontogenetic development and phylogenetic specialization of ray in the xylem of dicotyledons I. The primitive ray structure. *Am. J. Bot.* 27:918-928.

Barghoorn ES. 1941a. The ontogenetic development and phylogenetic specialization of rays in the xylem of dicotyledons. II. Modification of the multiseriate and uniseriate rays *Am. J. Bot.* 28:273-282.

Barghoorn ES. 1941b. The ontogenetic development and phylogenetic specialization of rays in the xylem of dicotyledons. III. The delimination of rays. *Bull. Torrey. Bot .Club*. 68:317-325.

Barghoorn ES. 1964. Elevation of cambium in geological time in Zimmermann M.H (ed) the formation of wood in forest Academic press, New York. 3-17.

Bartwal BS, Siddiqui FA & Iqbal M. 1983. Cambium structure in some Indian fruit trees. *Kalikasan. Philipp. J. Biol*. 12:61-69.

Braun HJ. 1955. Beitrage zue engtiwicklungsgeschichte der marjstrahlen. *Bot. Studien*. 4:73-131.

Butterfield BG. 1972. Development changes in the cambium of *Aeschynomene hipsida* willd. *N. Z. J. Bot.* 10:373-386.

Cheadle VI, Gifford EM & Esau K. 1953. A staining combination for phloem and contiguous tissues. *Stain Technol* 28:49-53.

Cheadle VI and Esau K. 1964. Secondary phloem of *Liriodendron tulipifera. Univ. Cal. Pab. Bot.* 36:143-252.

Cockerham G. 1930. Some observation on cambial activity and seasonal starch content in sycamore (*Acer Pseudoplatanus*). *Proc. Leed. Phil. Lit. Soc. Sci. Sec*. 2:64-80.

Cumbie BG. 1963. The vascular cambium abd xylem development in *Hibiscus lasiocarpus*. *Am. J. Bot.* 56:139-146.

Cumbie BG. 1969a. Development changes in the vascular cambium of *Leitneria floridana*. *Am. J. Bot*. 54:414-424.

Cumbie BG. 1969b. Development changes in the xylem and vascular cambium of *Apocynum sibiricum*. *Bull. Torr. Bot. Club*. 96:429-440.

Cumbie BG. 1983. Development changes in wood of *Baccomia volcanic*. *IAWA Bull*. 4:131-140.

Dave YS, Rao KS. 1982. Cambial activity in *Mangifera indica* L. *Acta Bot Acad Sci Hung*., 28:73-79.

De-Barry A. 1884. Comparative anatomy of the vegetable organs of the phanerogams and ferns. Clarendon Press, Oxford.

Eames AJ and Mac-Daniels LH. 1947. An introduction to plant anatomy. Mc Graw Hill book Co., New York.

Esau K. 1965. "Plants Anatomy". John Wiley, New York.

Esau K. 1977. "Plant Anatomy". John Wiley & Sons Inc. New York.

Esau K. 2002. Anatomy of seed plants, 2nd ed. John Wiley & Sons (Asia) Pvt. Ltd., Singapore.

Evert RF.1959. Ray origin in *Pyrus communis* L. 9th Intl. Bot. Cong. 2:108.

Evert RF. 1961. Some aspects of cambial development in *Pyrus communis*. *Am. J. Bot*. 48:479-88.

Evert RF. 1963a. The cambium and seasonal development of phloem in *Pyrus malus Am. J. Bot*. 50:8-37.

Fahn A. 1974. Plant anatomy, 2nd ed. Pargamon press, Oxford.

Fahn A. 1982. Plant anatomy, 3nd ed. Pargamon press, Oxford.

Fahn A. 1997. Plant anatomy, IVth edn. Pargamon press, Oxford.

Foster AS. 1934. The use of tannic acid and iron chloride for staining cell walls in meristematic tissue. *Stain. Technol*. 9:91-92.

Gamble JS. 1972. A manual of Indian timbers, Bishen singh, Mahendra Pal Singh Dehradun India.

Ghouse AKM and Iqbal M. 1975. A comparative study on the cambial structure of some arid zone species of *Acacia* and *Prosopis. Bot. Notiser* 128:327-331.

Ghouse AKM and Iqbal M. 1977. Variation trends in the cambial structure of *Prosopis spicigera* L. in relation to the girth of the tree axis. *Bull. Torr. Bot. Club*. 104:197-201.

Ghouse AKM and Jamal A. 1979. Sieve-tube proportion in the secondary phloem of some *Cassia spp*. *Bull. Soc. Bot. Fr*. 126:207-212.

Ghouse AKM and Yunus M. 1973. Some aspects of cambial development in the shoots of *Dalbergia sissoo* Roxb. *Flora* 162:549-558.

Ghouse AKM and Yunus M. 1974a. Cambial structure in *Dalbergia*. *Phytomorphology* 24:152-158.

Ghouse AMK and Yunus M. 1974b. The ratio of ray and fusiform initials in some woody species of the *Ranalian* complex. *Bull Torrey Bot. Club*. 101:363-366.

Ghouse AKM, Iqbal M, Khan S Khan AH. 1980. Comparative study on the structure of vascular cambium in some Verbenaceae. *Phytomorphology* 30:32-40.

Grew N. 1682. The anatomy of plants. W. Rawlings, London.

Han KS and Woong YS. 1991. Development changes of cambial initials and their derivative cell in the trunk of *Diospyrus khaki* Thumb and *Firmiana simples* W.F, Wight in relation to girth increase. *Korean. J. Bot*. 34:191-199.

Han KS, Woong YS. 1993. Comparative anatomy of vascular cambium and its derivative tissues in decapitated *Populus eurameriaria*. *Korean. J. Bot*., 36:251-257.

Iqbal M. 1979. Studies on the structure and activity of vascular cambium in *Acacia nilotica var. telia* and *Prosopis spicigera*. Ph.D Thesis, Aligarh Muslim University, Aligarh.

Iqbal M. 1990. The vascular cambium. Research studies press ltd. Taunton. Somerset, England.

Johansen DA. 1940. Plant Microtechnique. McGraw-Hill Book company,Inc., New York.

Kafeel K. 1986. Seasonal variation in cambial activity of some Indian tropical trees. Ph.D Thesis Aligrah Muslim University, Aligarh.

Khan HA. 2001. Studies on the seasonal variation of phloem and xylem production in some tropical trees. Ph.D. thesis Aligarh Muslim university, Aligarh.

Khan MA and Siddiqui MB. 2007a. Ratio of fusiform and ray initials in Mousami(*Citrus sinensis*). *Ind . J. Applied & Pure Bio*. 22:175-178.

Khan MA and Siddiqui MB. 2007b. Ratio of fusiform initials in *Citrus limon* (Linn.) Burm.f. *Ind .J. Applied & Pure Bio*. 22:531-538.

Khan MA and Siddiqui MB. 2007c. Size Variation in the vascular cambium and its derivatives in two *Alstonia species*.*Acta bot . bras*. 21:531-538.

Khan MA, Khan MIH, Siddiqui MB and Bhat S. 2005. Ratio of ray and fusiform initials in some *Citrus* species . *Vegetos* 18:99-101.

Khan MIH. 1977. The anatomical study of the growth activities of guava. Ph.D thesis, Aligarh Muslim University, Aligarh.

Khan MIH and Siddiqui TO. 1980. Amount of fusiform initials in the Vascular cambium of *Eucalyptus citriodora* Hk. *Jour. Sci res*. 2:17-18.

Khan MIH and Siddiqui TO. 1983. Ratio of ray and fusiform initials in the Vascular cambium of some *Moraceae*. *Geobios.* 2:82-83.

Khan MIH, Siddiqui TO and Khan S. 1983. Ontogenetic changes in the cambial structure of *Citrus sinensis*. L. *Flora*. 173:151-158.

Khan, MIH, Lutfia BA and Khan S. 1988. Comparative study on the structure of vascular cambium in some *Citrus spp.* growing in Mediterranean climate. Indian *J.Applied & Pure Bio*. 3:87-91.

Khan S. 1980. Studies on seasonal activity of vascular cambium and secondary phloem in some Myrtaceae.Ph.D thesis , Aligarh Muslim University. Aligarh.

Khan HA. 2001. Studies on the seasonal variation of phloem and xylem production in some tropical trees. Ph.D thesis Aligarh Muslim university, Aligarh.

Khan MA, Khan MIH, Siddiqui MB and Bhat S. 2005. Ratio of ray and fusiform initials in some *Citrus species*. *Vegetos* 18:99-101.

Khan MA, Siddiqui MB, Bhat S and Shahab D. 2007. Pollution effect on the cambial structure of some *Citrus reticulata* var. tangelos. *Int. J. Bot.* 3:342-350.

Khan MIH, Siddiqui TO and Khan S. 1983. Ontogenetic changes in the cambial structure of *Citrus sinensis*. L. *Flora*. 173:151-158.

Kozlowski TT. 1971. Growth and development of trees Vol.II. Academic Press, New York & London.

Mahmood A. 2001. Studies on growth activities of some tropical trees. Ph..D thesis , Aligarh Muslim University. Aligarh.

Margaris NS and Popadogianni P. 1977. The ratio of ray and fusiform initials in some plants dominating Mediterranean formations in Greece. *Flora*. 166:219-222.

Metcalfe CR and Chalk L. 1950. Anatomy of the dicotyledons Vol. I. The Claredon press, Oxford.

Murmanis L. 1970. Locating the initials in the vascular cambium of *Pinus strobus* L. by electron microscopy .*Wood Sci. and Tech*., 4:1-14.

Murmanis L. 1971. Structural changes in the vascular cambium of *Pinus strobus* L. during an annual cycle .*Ann. Bot*., 55:133-141.

Newman IV. 1956. Patterns in meristems of vascular plants. I.cell partition in living apicies and in the cambial zone in relation to the concepts of initial cells and apical cells. *Phytomorphology* 6:1-19.

Paliwal SP and Yadav A. 1999. Variations in the size of fusiform initials, xylem fibres and vessel elements along the axis and across in the stem of *Leucaena leucocephala* (Lam) *De.Wit. Pcinl*. 29:47 -51.

Paliwal SP, Rajat, Usha, Yadav, Anita and Yadav A. 2002. Size correlations among cambial initials and their derivatives in *Haldina cordifolia* (Roxb.) Ridsdale National Conf. Palaco Bot .Soc. Lucknow. 50:28-29.

Philipson WR, Ward JM and Butterfield BG. 1971. The vascular cambium, its development and activity. Chapman & Hall, London.

Rajput KS, Rao KS. 1999. Seasonal distribution of starch in *Tectona grandis* L.f and *Acacia nilotica* (L.)Del. Growing in different forests of Gujarat state. *Phytomorphology* 49:209-214.

Rao RV, Sujatha M, Shashikala S, Sarma CR (1996). Wood anatomical variation in certain hardwood trees-Part II .*J. Timber Dev. Assoc. India*. 47(4):25-38.

Rao KS. 1988. Cambial activity and development changes in ray initials of some tropical trees. *Flora (Jena)*. 181:425-439.

Rao KS and Dave YS. 1986. Developmental changes in the fusiform initials of some tropical trees. *Flora (Jena)* 177:187-194.

Rensing KH and Samuel AL. 2004. Cellular changes associated with rest and quiescence in winter –dormant vascular cambium of *Pinus contorta*. *Trees* 18:373-380.

Robards AW and Kidwai P. 1969. A comparative study of the ultra structure of resting and active cambium of *Salix fragilis* L. *Planta* 84:239-249.

Sanio C. 1863. Vergleichede untersuchungen uber die zusammensetzung. Des Holkopers. Bot., 21: 357-363; 369-375; 377-385; 389-399; 401-412.

Srivastava LM. 1996. On the fine structure of the cambium of *Fraxinus americana* L. J. Cell Biol. 31:1-142.

Srivastava IM and O`Brien TP. 1966. On the ultrastructure of the cambium and its derivatives .I. Cambium of *Pinus strobus* L. *Protoplasm*. 61:257-576.

Siddiqui TO. 1983. Studies on seasonal activity of vascular cambium and secondary phloem in some

Moraceae. Ph.D thesis Aligarh Muslim University. Aligarh.

Venugopal N and Krishnamurthy KV. 1989. Organization of vascular cambium during different seasons in some tropical timber trees. *Nord. J. Bot*. 8:631-638.

Venugopal N and Liangkuwang MG. 2007. Cambial activity and annual rhythm of xylem production of elephant apple tree (*Dillenia indica* Linn.) in relation to phenology and climatic factor growing in sub-tropical wet forest of northeast India. *Trees* 21:101-110.

Wani BA and Khan A. 2008. Ratio of fusiform and ray initials in *Juglans regia* L from temperate climate of Kashmir Himalaya. *Indian J. Applied and pure Bio*., 23:63-66.

Wani BA and Khan A. 2009. Ratio of fusiform and ray initials in *Robinia pseudoacacia* L from temperate climate of Kashmir Himalaya. *Indian J. Applied and pure Bio*. 24:259-261.

Wani BA and Khan A. 2010. Effect of cement dust pollution on the vascular cambium of *Juglans regia* L. *J. Ecol. Nat. Environ.* 2(10):225-229.

Whalley BE. 1950. Increase in girth of the cambium in *Thuja occidientials* L. *Can. J. Res*., 28:331-340.

Wilson BF. 1963. Increase in cell wall surface area during enlargement of cambial derivatives in *Abies concolor*. *Am. J Bot*., 50:95-102.

Zagorska-Marek B. 1984. Pseudotransverse divisions and intrusive elongation of fusiform initials in storeyed cambium of Tilia. *Can. J. Bot*., 62:20-27.