东北两种桦木导管和纤维细胞特征及其与气候关系

白 鑫[1] 刘昌鑫[1] 王晓春[1*]

（1. 东北林业大学生态研究中心，森林生态系统可持续经营教育部重点实验室，哈尔滨 150040）

摘 要:【目的】明确桦木属树种在气候影响下，树干导管及木纤维细胞对气候的响应与适应策略，从而更好地理解宏观生长－气候关系，为预测东北地区温带森林生产力与植被生产力提供理论基础与科学依据。【方法】本研究主要以黑龙江凤凰山国家森林公园内的白桦(*Betula platyphylla*)和枫桦(*Betula costata*)为研究对象，运用树木年代学和木材解剖学方法，测量并比较了 2 种桦木年轮宽度(RW)、导管数量(VN)、平均导管面积(MVA)、导管总面积(TVA)、导管密度(VD)、特异性导水率(K_s)、理论导水率(K_h)、导管占比(RVTA)；木纤维细胞数量(FN)、木纤维细胞总面积(TFA)、平均木纤维面积(MFA)、纤维细胞密度(FD)、木纤维细胞厚度(CWTall)和木纤维细胞占比(RFTA)等指标，分析二者导管和木纤维细胞特征与主要气候因子关系、时间稳定性及各参数对极端气候的抵抗力与恢复力。【结果】白桦和枫桦同属散孔材，分布范围广，适应能力强，木质部解剖结构相似，但仍存在显著差异。白桦与枫桦年轮宽度与导管数量为显著的正相关(p<0.05)。枫桦导管大而少，木纤维细胞小，且木纤维细胞壁较厚；白桦导管小但数量多，木纤维细胞较大且多。白桦和枫桦径向生长主要受到气温和水分因子的限制，且相对于导管解剖特征而言，气候因素对木纤维细胞特征的影响较弱。随着气候变暖，白桦受到降水的影响增强，导管数量更多但导管更小。而枫桦则采取减少导管数量，增加导管大小来适应环境；白桦木纤维细胞的数量为增加的趋势，但枫桦木纤维细胞的数量变化与其相反。白桦和枫桦径向生长对生长季干旱和非生长季高温的抵抗力和恢复力趋势基本相同，无显著差异，且两者对非生长季高温的抵抗力和恢复力均较低。【结论】本研究发现不同桦木木质部导管和木纤维细胞应对气候变暖的策略不同，不能单纯用科属来整体探究树种生长机制与适应策略。白桦主要产生较多较小的导管来维持水力安全，并增多木纤维细胞来保证正常的径向生长量。枫桦则采取大导管来提高水分运输效率，但同时，枫桦发生栓塞的概率更大，从而可能导致其率先死亡。

关键词: 桦木；木质部解剖；导管；木纤维细胞；气候变化

characteristics of tree trunk xylem vessels and fibre cells of two species of *Betula* in northeast China and their relationships with the climate

Abstract:【Objective】To clarify the response and adaptation strategies of trunk conduits and wood fibre cells of *Betula* spp. to climate under the influence of climate, so as to better understand the macroscopic growth-climate relationship, and to provide theoretical basis and scientific evidence for the prediction of the productivity of temperate forests and vegetation productivity in Northeast China. 【Method】In this study, we measured and compared the annual ring width (RW), vessel number (VN), mean vessel area (MVA), total vessel area (TVA), vessel density (VD), specific theoretical hydraulic conductivity (K_s), theoretical hydraulic conductivity (K_h), mean percentage of vessel area within xylem (RVTA), fiber cell number (FN), total fiber cell area (TFA), mean fiber cell area (MFA), fibre cell density (FD), overall mean thickness of all fiber cell walls (CWTall) and mean percentage of fiber cell area within xylem (RFTA), etc., and analysed the relationship of the characteristics of the two species with seasonal and wood fibre cell characteristics. We analysed the relationship between conduit and wood fibre cell characteristics and seasonal climatic factors, temporal stability, and growth resistance and resilience to climatic

extremes in both species. 【Result】*B. platyphylla* and *B. costata* belong to the same genus of bulkhead timber, with wide distribution range, strong adaptive ability, and similar xylem anatomical structure, but there are still significant differences. There was a significant positive correlation between the width of annual rings and the number of conduits between *B. platyphylla* and *B. costata* ($p<0.05$). *B. costata* had large and few conduits, small wood fibre cells and thicker wood fibre cell walls; *B. platyphylla* had small but numerous conduits and larger and more wood fibre cells. Radial growth of *B. platyphylla* and *B. costata* was mainly limited by temperature and moisture factors, and the effect of climatic factors on the characteristics of wood fibre cells was weak relative to the anatomical characteristics of the ducts. As the climate warmed, *B. platyphylla*, due to the influence of precipitation, had a greater number of conduits, but smaller conduits. *B. costata*, on the other hand, adapted to the environment by decreasing the number of ducts and increasing their size; the number of *B. platyphylla* wood fibre cells tended to increase, but the opposite was true for *B. costata* wood fibre cells. *B. platyphylla* and *B. costata* radial growth resistance and resilience to growing season drought and non-growing season high temperature trends were basically the same, no significant difference, and both of them had lower resistance and resilience to non-growing season high temperature. 【Conclusion】 In this study, we found that different birch xylem conduits and wood fibre cells had different strategies to cope with climate warming, and we could not explore the growth mechanism and adaptation strategy of the tree species as a whole by using the family alone. Birch mainly produces more and smaller conduits to maintain hydraulic safety and more wood fibre cells to ensure normal radial growth. *B. costata*, on the other hand, adopts large conduits to increase the efficiency of water transport, but at the same time, *B. costata* has a greater probability of embolism, which may result in *B. costata* being the first to die.

Key words: *Betula*; xylem anatomy; vessel; wood fiber cell; climate change

基金项目：国家自然科学基金(41877426 和 42177421)

* 王晓春为通讯作者