物生态学报
se Journal of Plant Ecology
ISSN 1005-264X
CN 11-3397/Q
邮发代号：82-5

植物生态学报 » 2011, Vol. 35 » Issue (4) :411-421 DOI: 10.3724/SP.J.1258.2011.00411

华北落叶松树体储水利用及其对土壤水分和潜在蒸散的响应：基于模型模拟的分析

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摘要 树体储水在树木水分传输中具有重要的作用，不仅为蒸腾提供水分来源，还具有缓冲作用，可防止木质部导管水势过低以至于水分传输的失败。树体储水动态及其利用的研究对于认识树木对水分胁迫的响应机制具有重要意义。该研究构建了包含树体储水释放-补充作用的树干水分传输模型，可模拟计算林分小时尺度的冠层蒸腾、边材液流、树体储水与木质部导管水流交换过程，并以六盘山北侧的华北落叶松(*Larix principis-rupprechtii*)人工林为例，在林分水平分析树体储水利用及其 与土壤水分和潜在蒸散之间的关系。检验结果表明，该模型能够精确地模拟出林分边材液流的日变化特征，模拟与观测的小时液流速率决定系数R^2为0.91 (n = 2 352)。模拟结果表明，在典型晴朗天气下，在日出时树体储水利用启动，至9:00左右达到峰值(0.14 mm?h^{-1})，午间降至0，下午降为负值直至午夜，即进入树体补水阶段；树体储水日使用量(DJ_z)为0.04 – 0.58 mm?d^{-1}，与日蒸腾量(DT_r)成正相关(R^2 = 0.91)，对蒸腾的贡献为25.6%。分析结果表明，当潜在蒸散(ET_p)低于4.9 mm?d^{-1}时，ET_p是华北落叶松树体储水利用的主要驱动因子，DJ_z与ETp成正相关(R^2 = 0.68)；当ET_p高于4.9 mm?d^{-1}时，DJ_z随着ET_p的增加呈现降低趋势；DJ_z与土壤水势没有显著相关关系(p > 0.05)，但最大树体储水日使用量(DJ_{zmax})与土壤水分含量成正相关(R^2 = 0.79)，说明土壤水分是树体储水利用的限制因子。

关键词： 华北落叶松 边材液流 树干水分传输模型 树体储水

Abstract： *Aims* Water stored in the secondary xylem of the sapwood of large trees is not only a source for transpiration, but also may help avoid xylem cavitation and subsequent failure of water transfer in xylem. Our objective was to study the dynamics of tree water storage and use in order to understand the response mechanism of trees to water stress. *Methods* A model simulating the diurnal pattern of water transfer within stems was designed. It combines a non-steady-state hydraulic model with a transpiration model that was based upon the Penman-Monteith equation and a Jarvis-type representation of the stomatal resistance including xylem conduct water potential (ψ_{hx}), vapor pressure deficit (D_s) and photosynthetically active radiation (IP). The combined model simulates the diurnal variation of water uptake, storage flow and transpiration rate directly from environmental variables. We simulated the sap flow of *Larix principis-ruprechtii*, which is planted in Diediegou catchments on the north sides of the Liupan Mountains, and analyzed the relationship between storage water use and environmental factors. *Important findings* The hydraulic model accurately simulated diurnal patterns of measured sap flow under microclimatic conditions; the coefficient of determination (R^2) between observed and simulated sap flow velocity in calibration sets was 0.91 (n = 2 532). On a typical sunny day, the highest rate of storage water use started at about 9:00 AM, decreased to zero at noon and turned to recharge throughout the afternoon until midnight. The daily storage water use varied between 0.04 and 0.58 mm?d^{-1} and was positively related to transpiration. Storage water provided 25.5% of transpiration water. When potential evapotranspiration (ET_p) was < 4.9 mm?d^{-1}, daily storage water use (DJ_z) was positively related to ET_p. DJ_z linearly increased with ET_p as ET_p increased, but decreased correspondingly when ET_p was >4.9 mmd^{-1}. There was no significant relationship between DJ_z and soil water potential (p > 0.05), but the maximum DJ_z was positively related to soil water potential (R^2 = 0.79). Therefore, ET_p is the primary driving factor of water storage use, and soil water potential is the limiting factor.

Keywords： *Larix principis-ruprechtii*, sap flow, stem water transfer model, tree water storage

收稿日期: 2010-11-12; **出版日期**: 2011-04-01

基金资助:

干旱缺水区土地覆被变化对区域耗水的影响;干旱缺水地区森林生长固碳与生态耗水的关系;西北典型区域基于水分管理的森林植被承载力研究;多功能林业理论及典型地区案例研究;产水对半湿润/干旱土地利用与气候变化的响应

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引用本文:

孙林, 熊伟, 管伟, 王彦辉, 徐丽宏. 华北落叶松树体储水利用及其对土壤水分和潜在蒸散的响应: 基于模型模拟的分析. 植物生态学报, 2011,35(4): 411-421.

SUN Lin, XIONG Wei, GUAN Wei, WANG Yan-Hui, XU Li-Hong. Use of storage water in *Larix principis-ruprechtii* and its response to soil water content and potential evapotranspiration: a modeling analysis. Chinese Journal of Plant Ecology, 2011,35(4): 411-421.

链接本文:

http://www.plant-ecology.com/CN/10.3724/SP.J.1258.2011.00411 或 http://www.plant-ecology.com/CN/Y2011/V35/I4/411

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